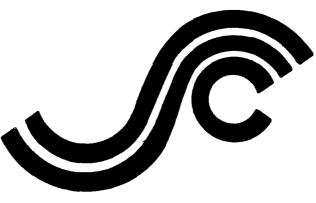


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A RATIONAL BASIS FOR THE SELECTION OF ICE STRENGTHENING CRITERIA FOR SHIPS VOLUME II-APPENDICES



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SHIP STRUCTURE COMMITTEE

1981

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The SHIP STRUCTURE COMMITTEE is constituted to prosecute a research program to improve the hull structures of ships and other marine structures by an extension of knowledge pertaining to design, materials and methods of construction.

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Deputy Assistant Administrator for
Commercial Development
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LCdr D. B. Anderson, U.S. Coast Guard (Secretary)

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The SHIP STRUCTURE SUBCOMMITTEE acts for the Ship Structure Committee on technical matters by providing technical coordination for the determination of goals and objectives of the program, and by evaluating and interpreting the results in terms of structural design, construction and operation.

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An Interagency Advisory Committee Dedicated to Improving the Structure of Ships

SR-1267

1981

As marine activity in ice covered waters is expected to increase in the foreseeable future, the design of ships to meet the varying conditions will have an expanding role for the naval architect.

The Ship Structure Committee has undertaken a program to acquire the necessary knowledge to permit a rational design for vessels which will be operating in various ice conditions. This first effort in the program surveyed the various classification societies and government regulations in order to discorn the similarities and differences of their requirements, and further to recommend a procedure for selecting appropriate ice strengthening criteria. The results of this project are being published in two volumes. Volume I (SSC-309) contains the analytical portion of the work and Volume II (SSC-310) contains the appendices.

Rear Admiral, U.S. Coast Guard Chairman, Ship Structure Committee

1. Report No. SSC-310	2. Government Access		3. Recipient's Catalog No.
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9. Performing Organization Name and Add			10. Work Unit No. (TRAIS)
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Columbia, Maryland 210)45		DOT-CG-904937-A
12. Sponsoring Agency Name and Address		 	13. Type of Report and Period Covered Final Report
	•		20 August 1979 -
U.S. Coast Guard			26 May 1980
Office of Merchant Marine S	afety		14. Sponsoring Agency Code
Washington, D.C. 20593			G-M
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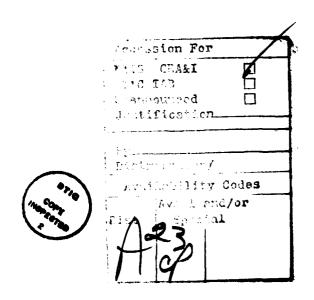
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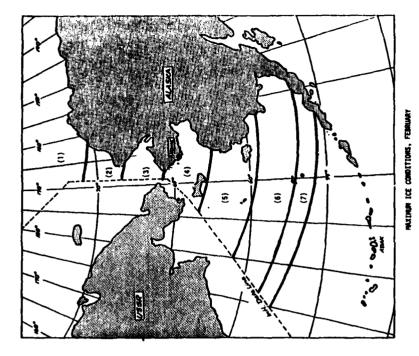
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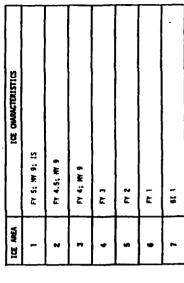
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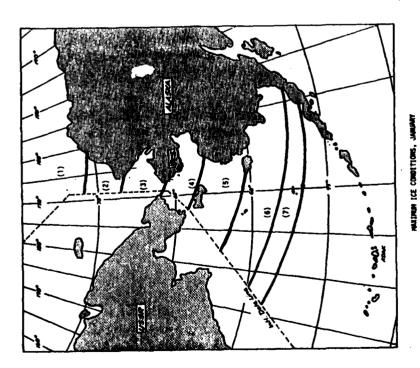
- A.1 Alaska
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- A.3 Antarctic
- A.4 Great Lakes
- A.5 Gulf of St. Lawrence
- A.6 Baltic Sea
- A.7 WMO Sea-Ice Nomenclature

Abbreviations used in this Appendix are as follows:

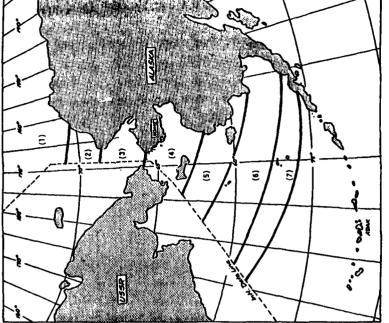
- FY = first-year ice
- MY = multi-year ice
- IB = iceberg, bergy bits, growlers, and any other fragments
- IS = ice island or fragment therefrom
- BI = broken ice
- XX = level ice thickness. The corresponding pressure ridge
 depth (water surface to keel depth) contained within
 level ice floes is ten times the level ice thickness.
 The depth of consolidation within the first-year pressure
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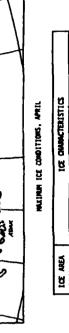






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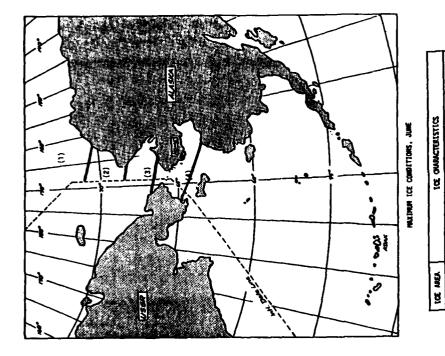
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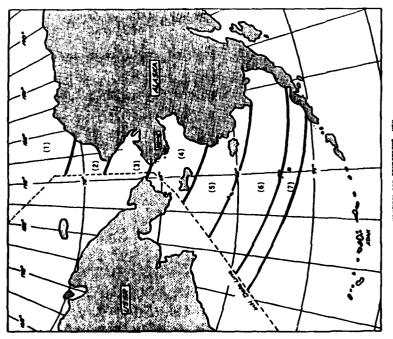
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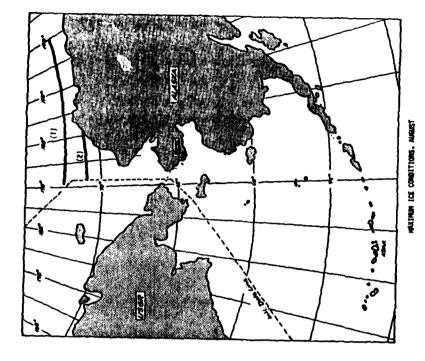




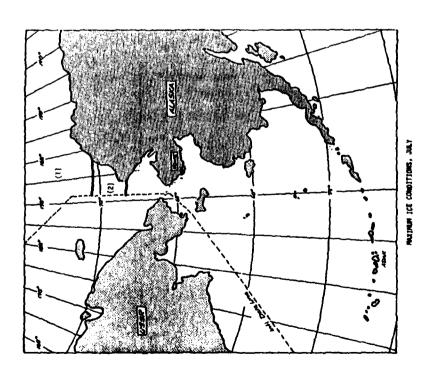
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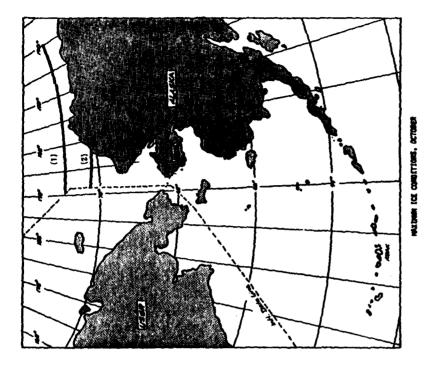
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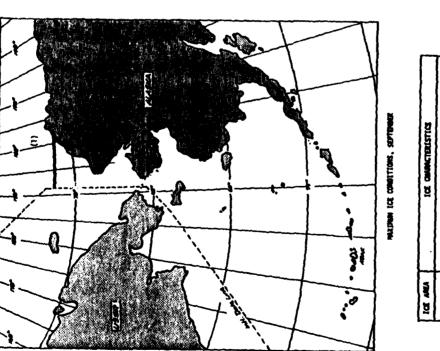


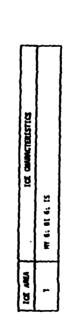


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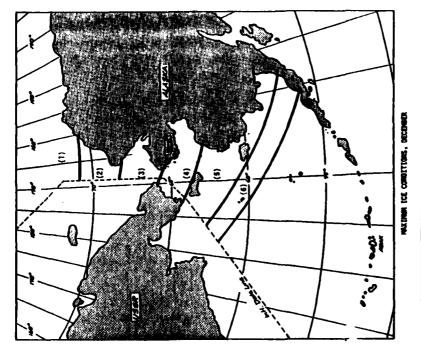


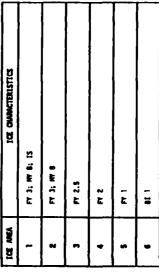
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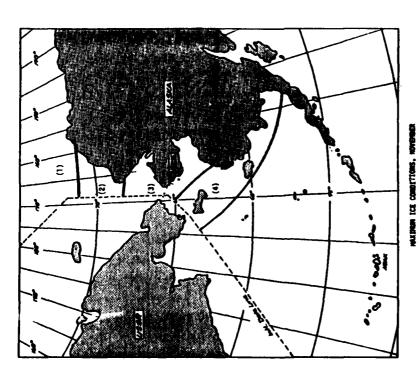
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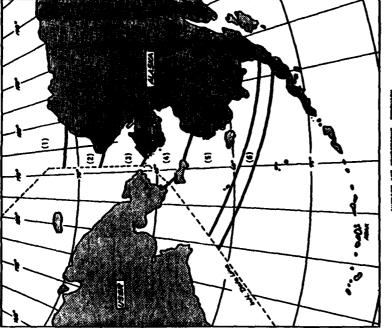
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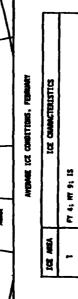






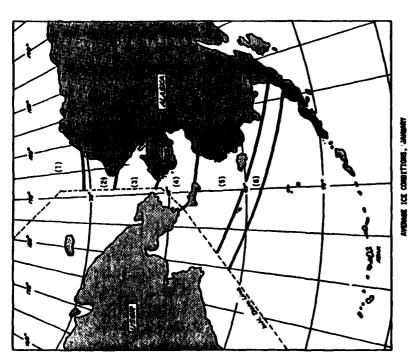
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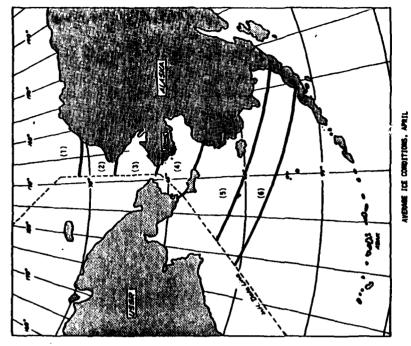
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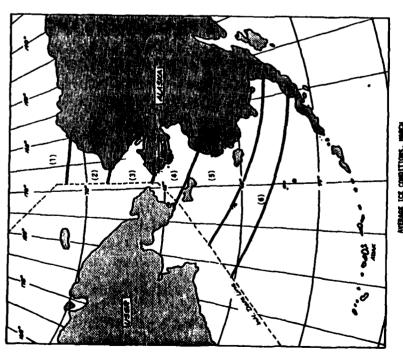


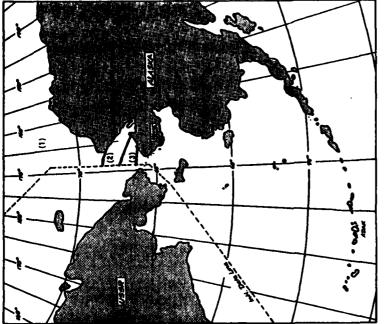
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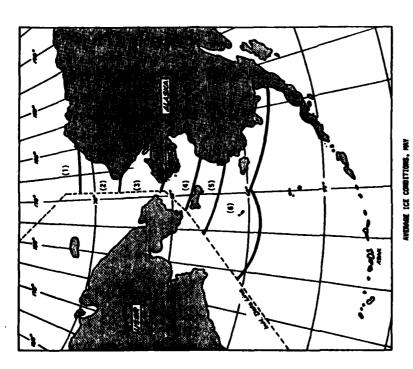
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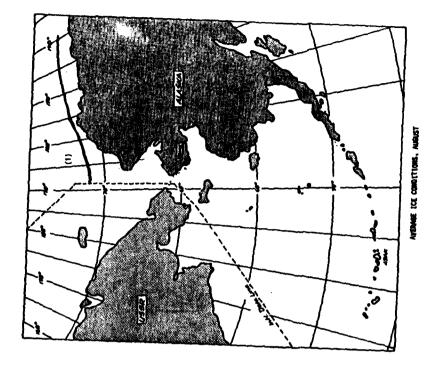


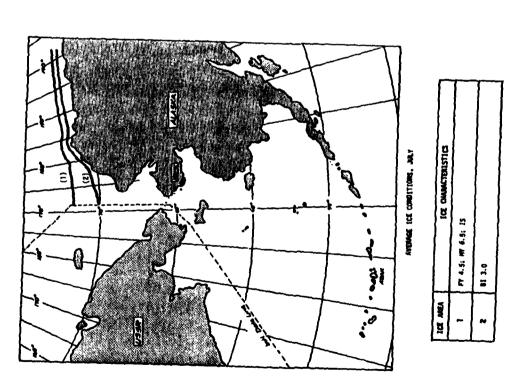


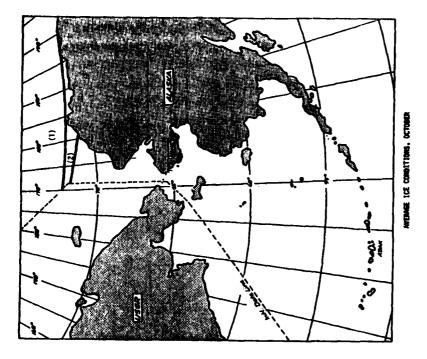
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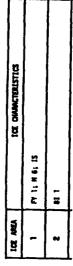


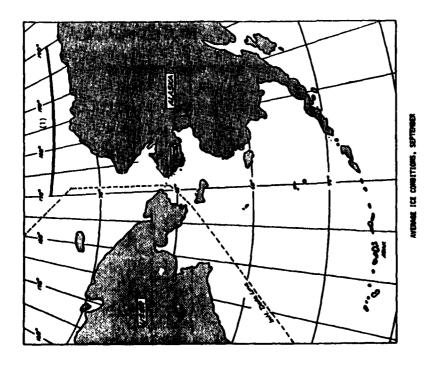
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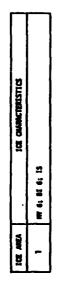


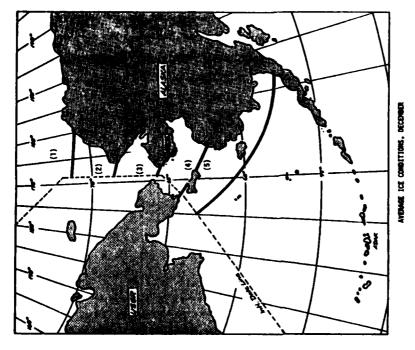




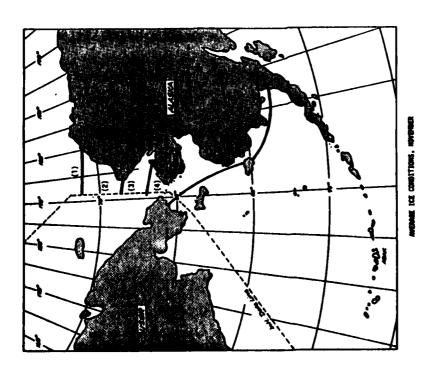








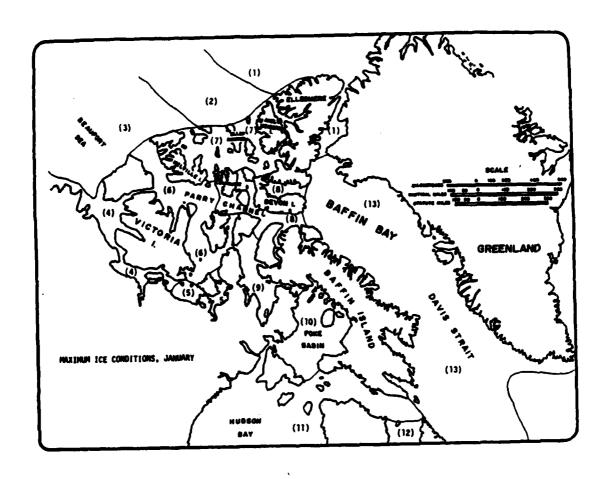
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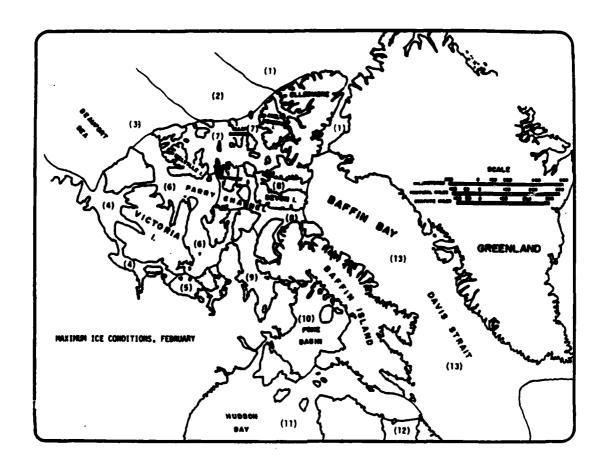
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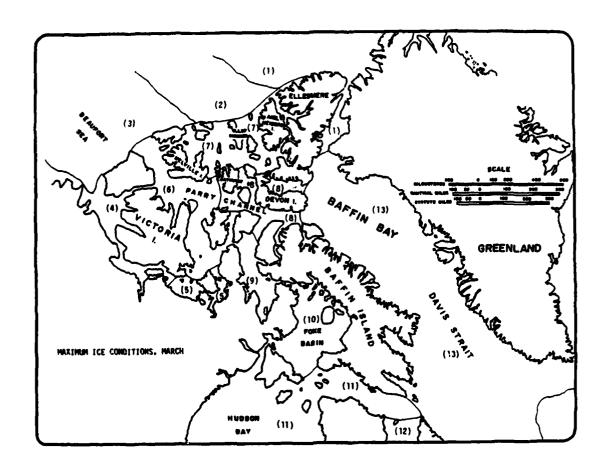
CANADA - MAXIMUM AND AVERAGE ICE CONDITIONS BY MONTH



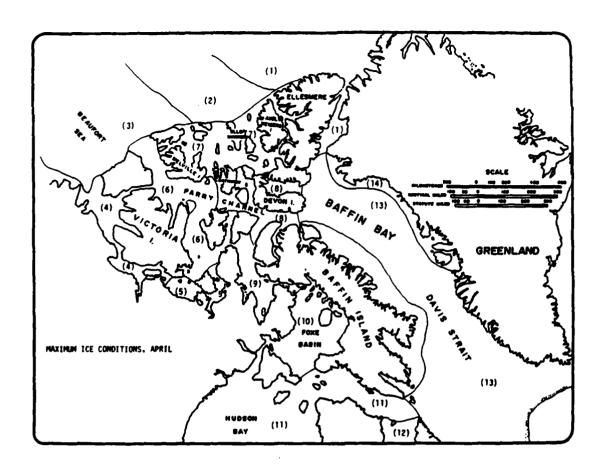
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4	FY 4.9-40; HY 10-40
5	FY 5.2-40
6	FY 4.8-40; NY 18-40; ice islands
7	PY 5.2-30; RV 18-40; ice islands
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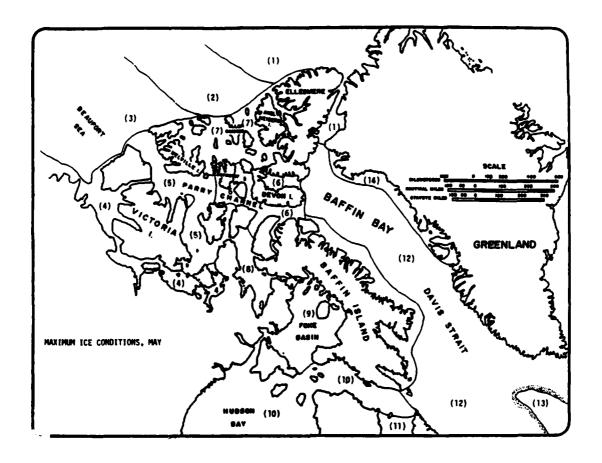
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4	FY 5.4-40; RY 18-40
5	FY 6.1-40
6	FY 5.6-40; NY 18-40; Ice Islands
7	FY 5,4-30; NY 18-40; Ice Islands
8	FY 5.4-40; icebergs, ice islands
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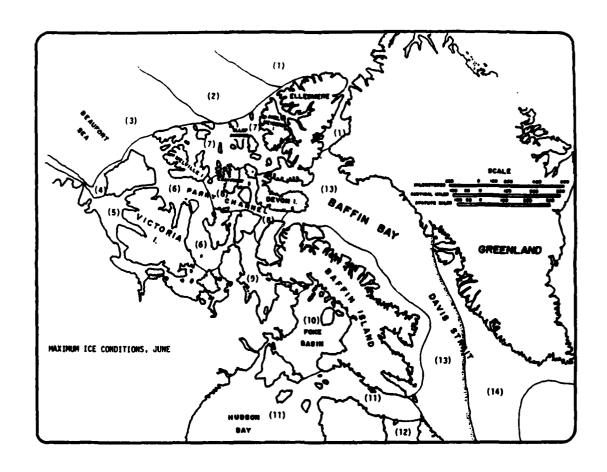
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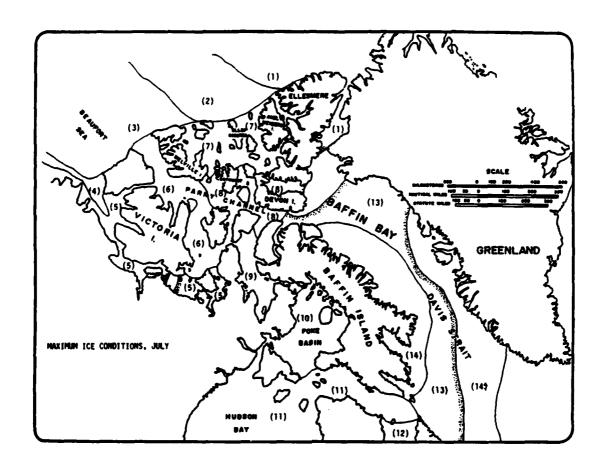
ICE AREA	ICE CHAMCTERISTICS
1	FV 7:9-40; NV 22-110; 1ce islands, icesergs
2	PV 8.0-60; IV 22-100; ice islande
3	FV 6.8-40; MY 22-90; 1ce islands
4	FY 7.2-40; HY 19-40
•	FY 7.3-4G
•	FV 6.9-40; NV 19-40; ice islands
7	FY 7.9-30; MY 19-40; ica islands
•	FY 6.7-40; icesergs, ice islands
,	FY 7.4-40; NY 19-40
10	FY 8.1-40; MY 13-40
11	FY 5.8-30; (caberys
12	77 5.8-25; 1coverys
13	BE 0.9-5.8; toppergs
14	FY 5.3-40; 1coberys



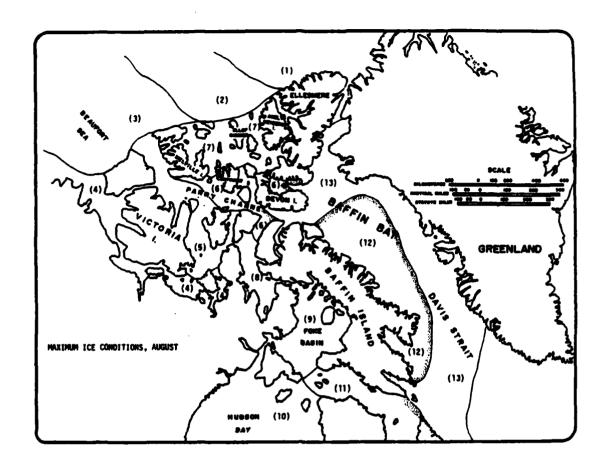
ICE AREA	ICE CHANCTERISTICS
1	FY 8.3-68; 117 22-110; 1ce Islands, Icoserys
2	FY 8.3-60; HY 22-100; 1co islants
3	FY 7.5-40: HF 22-40: 1sp islands
4	FY 7.1-40; RF 19-40
5	FY 7.1-40; HT 19-49
6	FY 6.6-40; icobergs, top islands
7	FY 5.5-30; HY 19-40; ice islands
•	FY 7.5-40; RY 19-40
,	FY 8.2-40; HY 13-40
10	FY 6.2-30; (coborgs
11	FY 5.5-25; features
12	9E 0.9-6.0; 1cohorgs
13	Conterpt
14	PY 5.5-40; 1cabergs



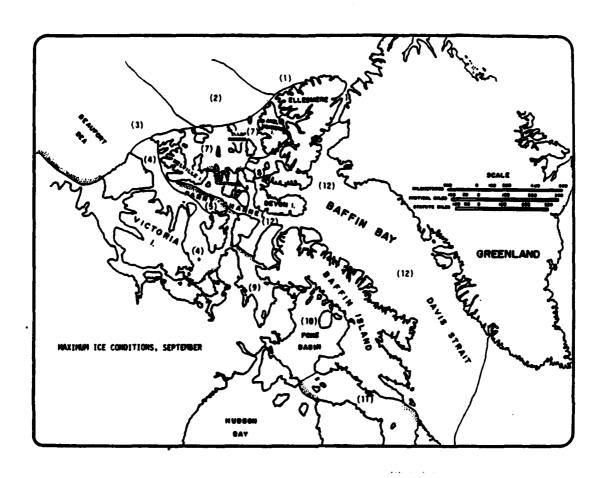
ICE AREA	toe guaracteristics
1	FY 7.7-60; NY 22-110; ice islands, icesergs
2	FV 8.2-60; HF 22-100; ion islands
3	FV 7.5-40; HV 22-90; 1ce 1slands
•	81 0. 9-6 .5
\$	FY 7.0-49; MY 19-40
6	FY 7,5-40; NY 19-40; (cobergs, 1ce islands
7	FV 8.0-30; FV 19-40; fce islands
8	FY 7,2-40; toe islands
,	FY 6.2-40; YY 19-40
10	FY 7.5-40; HF 19-40
11	FY 6.0-30; †caterys
12	FY 5.4-25; 1cohergs
13	\$1 3.9-5.0; (deergs
14	[copergs



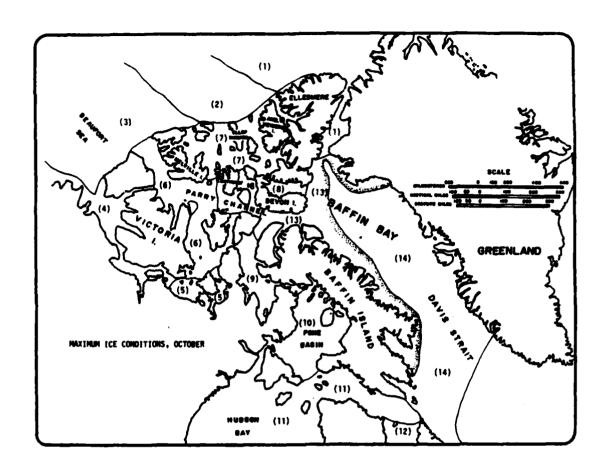
ICE AREA	. ICE QUANCTERISTICS
1	FY 6.0-60; MY 22-110; ice islands, icebargs
2	FY 7.5-60; HY 22-100; 1ce 1stands
3	FY 6.8-40; MY 22-90; ice islands
4	BI 9.8-4.8
5	FY 3.8-30; HY 19-40
6	FY 5.0-30; MY 19-40; fcebergs, fce islands
7	FY 7.2-30; MY 19-40; ice islands
•	FY 3.3-30;"ice islands
,	FY 4.2-30; HY 19-40
10	FY 5.0-30; 4Y 19-40
11	81 0.6-3.0; 1cobergs
12	SE 0.8-2.0; 1cesergs
13	81 0.7-3.5; (comergs
14	SI 0.8-3.5; 1cobergs



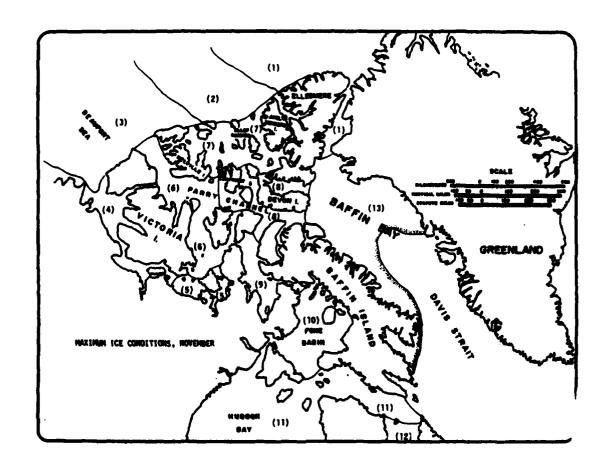
ICE AREA	ICE CHANCTERISTICS
1	FY 4.0-60; NY 20-110; 1ce islands. icabergs
2	FY 5.8-40; HY 20-100; 1ce islands
1	FY 5.5-40; MY 20-90; top islands
4	8\$ 0.6-2.6; 1cobergs
•	EE 0.9-5.0; forbergs, ice islands
•	SI 0.7-2.0; toegerge, toe islands
,	FY 4.5-30; HT 17-40; 1ce 1slands
•	FY 2.0-20; HT 17-40
•	FY 2.5-20: HY 17-40
10	81 0.5-1.5; formerys
11	BI 0.7-1.8; (cebergs
12	81 0.7-2.0; (cobergs
13	:conergs



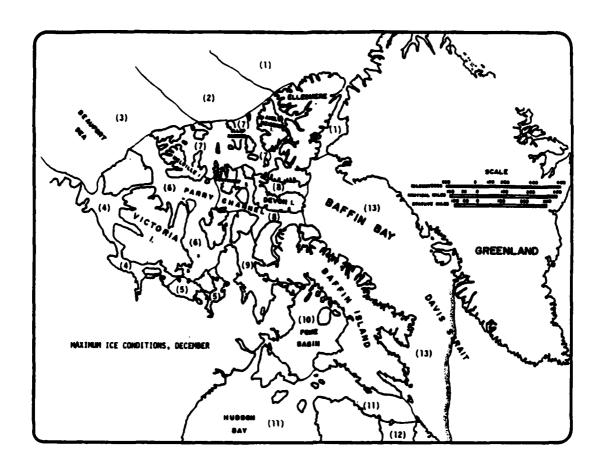
ICE AMEA	ICE CHARACTERISTICS			
1	FY 1.0-60; NY 20-11C; icebergs, ice islands			
2	FY 1.1-60; MY 20-100; fce islands			
3	FY 0.5-40; MY 20-90; (ce islands			
4	81 0.7-5.0; 1ce islando			
5	81 0.5-4.0; 1cebergs			
6	81 0.4-2.0; 1cebargs			
7	FY 0.8-30; MY 17-40; ice islands			
•	SI 0.8-4.5; 1ce islands			
•	FY 1.0-30; W 17-40			
10	81 0.7-1.5; 1ceberge			
11	BI 0.4-1.0; 1covergs			
12	Coebergs			



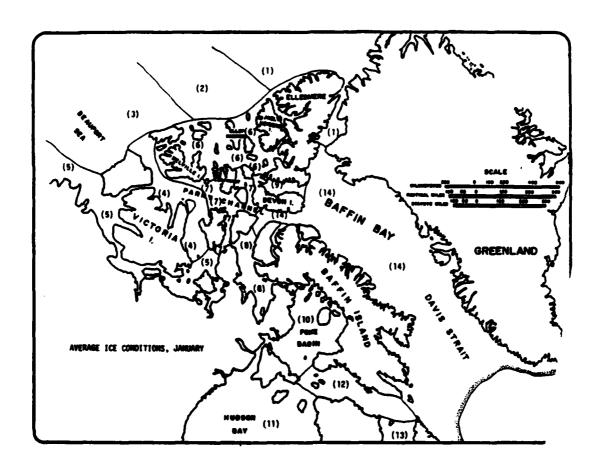
CE AMEA	ICE CHANCTERISTICS
1	FY 2.7-40; NY 18-110; ICE ISLANDS, ICEBERGS
2	FY 3.6-60; HY 18-100; CCE ISLANDS
3	PY 1.5-40; NY 18-90; CCE ISLANDS
4	FY 1.0-30; IN 16-46
5	FY 1.1-30
6	FY 1.3-30; HY 16-40; ICE ISLANDS
7	FY 2.0-30; NY 16-40; ICE ISLANOS
•	FY 1.2-40: HY 16-40
,	FY 1.2-30; NY 16-40
10	FY 0.8-30; CCEBERGS
11	FY 0.5-20; [CEBENGS
12	FY 0.8-20; [CEBERGS
13	8f 0.3-20; ;CEDENS
14	CEBERES



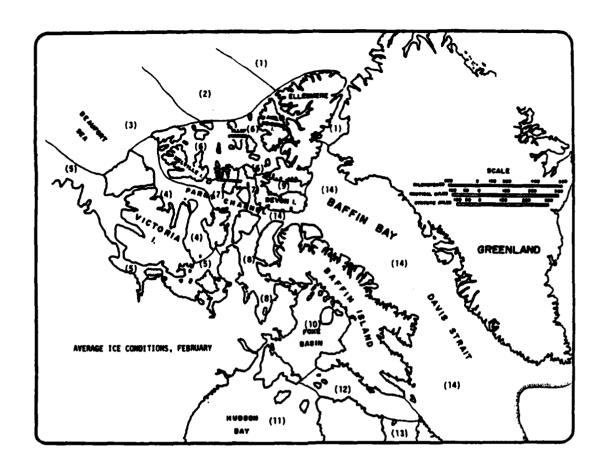
ICE AREA	ICE CHANCTERISTICS
1	PY3.7-00; HY 18-110; ICE ESLANDS, ICESERGS
2	F74.3-60; NV 18-100; TCE ISLANDS
1	PV2.7-40; HV 18-40; ICE ISLANDS
4	FY2.4-40;HV 16-46
5	FY2.0-40
6	FY2.7-401 NY 16-40; ICE ISLANDS
,	FY3.7-30; NY 16-40; CCE ISLANOS
	FY2.7-40: COEMERGE, COE ISLANDS
9	FY2.6-40; HY 16-40
10	FY3.0-40; HY 10-40
11	PY1.5-30; ICEBERGS
12	PY1.5-25; (CEREMES
13	810.9-1.4; :CEBERGS



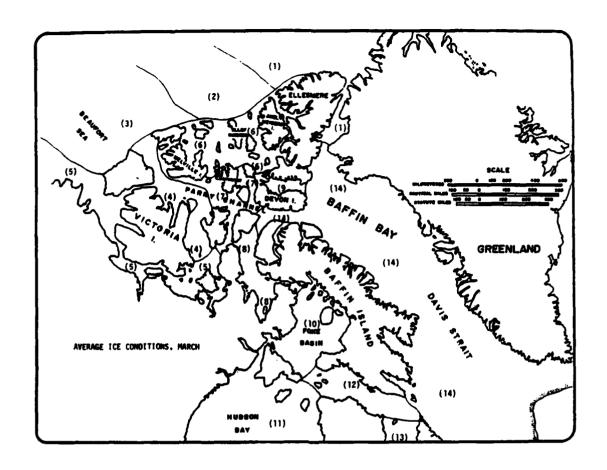
ICE AREA	ICE CHANGETERISTICS
1	FY 4.2-60; NY 20-110; ICE ISLANDS. ICEMENS
2	FY 4.8-40; NY 20-100; ICE ISLANDS
3	FY 4.1-40; MY 20-90; ICE ISLANDS
4	FY 3.8-40; HY 18-40
5	FY 3.8-40
•	PY 3.8-40; NY 18-40; ICE ISLANDS
7	FY 4.3-30; NY 18-40; ICE ISLANDS.
	PY 1.6-40; [CEBERGS, ICE ISLANOS
9	FY 3.6-40; ICEBERGS, ICE ISLANDS
10	FY 4.0-40; NY 12-40
11	FY 2.5-30; [CEBENAS
12	FY 2.0-25: [CEBERGS
13	al 0.9-2.8; [CEBERGS



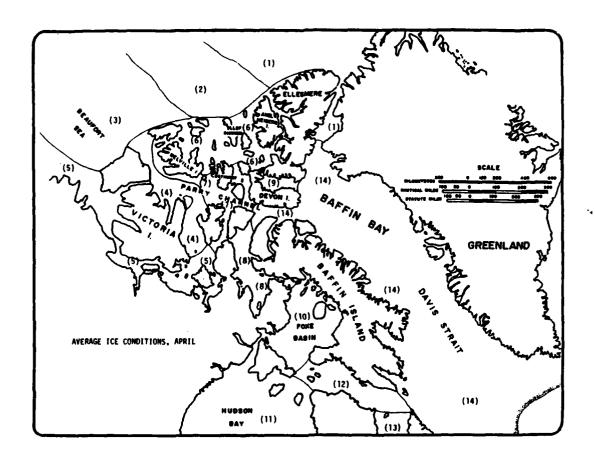
ICE AMEA	ECE CHANCTERESTICS
1	FY 4.5-00; NY 15.0-100; top islands
2	FT 4.2-00; NY 18.0-110; fce islands
3	FY 4.0-40; MY 15.0-40.0; top toleran
•	FÝ 3.9-40: NY 12.0-40.0
8	FY 3.6-25.0; RY 12.0-40.0
•	PY 4.5-25.0; HF 12.0-40.0
,	TV 3.9-30.Q; NV 10.0-40.0
•	PY 4.8-40.0
•	FY 4.3-21.0
10	PY 3.8-30.01 HY 19.0-40.0
11	FY 1.1-20.0
12	FY 2.5-25.0; feater#
13	FY 3.5-25.0; (caser#
14	81 9.9-3.0; icaser#



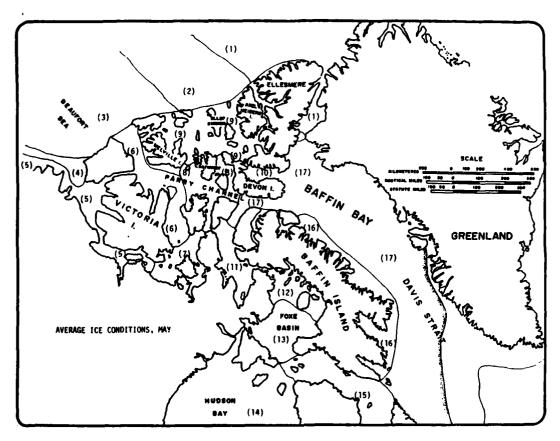
ICE AREA	ICE CHAMCTERISTICS
1	FY 5.1-68.0; MY 15.0-108.0; ice islands
2	FY 5.3-00.0: NY 15.0-110.0: 1ce Islands
3	FV 4.9-40.0; MY 15.0-40.0; too islands
4	FY 4.7-48.9; MY 12.0-40.0
•	FY 4.5-25.0; NY 12.0-40.0
6	FY 5.3-25.0; IN 12.0-40.0
,	FY 4.6-30.0; NY 10.0-40.0
•	PY 5.3-40.0
•	FY 5.0-25.0
10	FY 4.6-30.0; NY 15.0-40.3
11	FY 4.4-20.0
12	FY 4.0-25.3; 1ceserg8
13	fy 4,4-25,3; 1cobergs
. 14	3I J.9-3.4; fcebergs



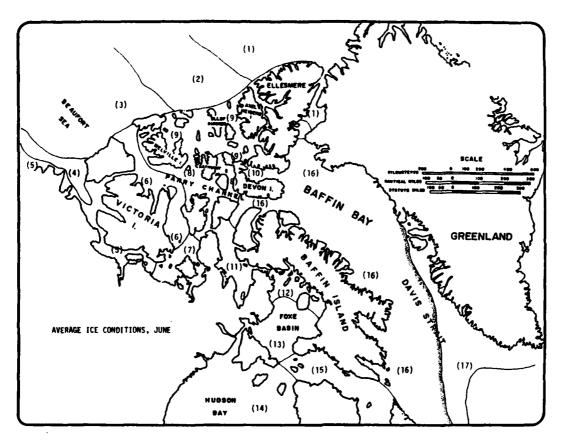
ICE AREA	ICE CHARACTERISTICS
1	FY 5.8-60.0; MY 17.0-100.0; fce fslands
2	FY 6.1-40.0; WY 17.0-110.0; ice islands
3	FY 5.3-40.0; NY 17.0-60.0; ice islands
4	FY 5.2-40.0; MY 14.0-40.0;
5	FY 5.6-25.9; HY 14.0-40.0
6	FY 6.3-25.0; MY 14.0-40.0
7	FY 5.2-30.0; 47 12.0-40.0
	FY 6.0-40.0:
9	FY 5.7-25.0
10	FY 5.4-30.0; Mt. 17.0-40.3
11	FY 4.9-20.0
12	FY 1.5-25.0: 'cepergs
13	FV 4.5-25.0; 'ceberys
14	\$1 3.9+3.8: 'Ceparys



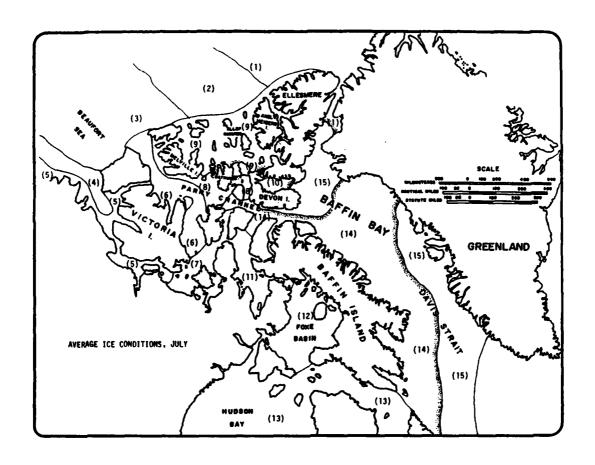
JOE AREA	ICE CHARACTERISTICS
1	FV 6.4-60.0; MY 17.0-100.0; 1cm 1slands
2	FY 6.8-60.0; RV 17.0-110.0; ice islands
1	FY 5.5-40.0; MY 17.0-60.0; tox islands
4	FY 5.4-49.01 NY 14.0-40.0
5	FY 6.0-25.0; HT 16.0-40.0
•	FY 6.9-25.01 NY 14.0-40.0
,	FY 5.7-30.0 HF 12.0-40.0
•	• FY 6.7-40.0
,	FV 5.2-25.0
10	FY 6.1-30.0; HY 17.0-40.0
11	FY 5.5-20.0
12	FY 5.1-25.0; !cobergs
13	FY 5.3-25.0: 1casers
14	31 3.3~4.2; 'cooorga



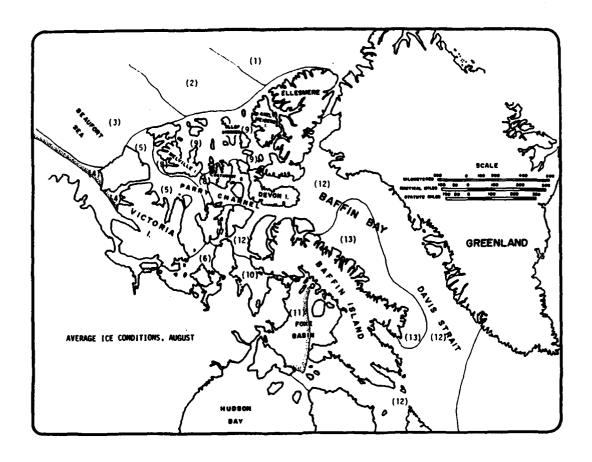
ICE AREA	ICE CHARACTERISTICS
1	FY 6.7-60; MY 18.0-100.0; ice islands
z	FY 7.3-60; NY 18.0-110.0: ice islands
3	FY 6.1-40.0; NY 18.0-60.0; 1cm 1slands
4	81 0.9-4.0
s	PY 6.7-25.0: MY 15.0-40.0
6	FY 6.5-40.0; MY 15.0-60.0
7	FY 7.0-40.0; HY 15.0-40.0
8	FY 6.0-30.0; MY 12.5-40.0
9	FY 7.4-25.0; \text{\tint{\text{\tin}\text{\tint{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\tint{\text{\tinit}\xitilex{\text{\text{\text{\text{\text{\tinit}\xitilex{\text{\te}\tinit}\xitilex{\text{\text{\text{\text{\tinit}\xitilex{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\texi}\tilititt{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\texi}\text{\text{\texi}\text{\texitilex{\text{\texitilex{\text{\texitilex{\texit{\texitilex{\texitilex{\texi{\texi}\tilitit{\texitilex{\tii}\tiint{\texitilex{\tiint{\texitilex{\t
10	ਜ 5.5-25.0
11	FY 7.0-40.0
12	FY 6.4-40.0
13	91 3.9-9.4
14	SE 0.9-5.5
15	\$[0.9-4.7; 'ceoorgs
16	FF 4,8-25.0
17	\$1 7,5-4.5; 'cepergs 1% (:epergs



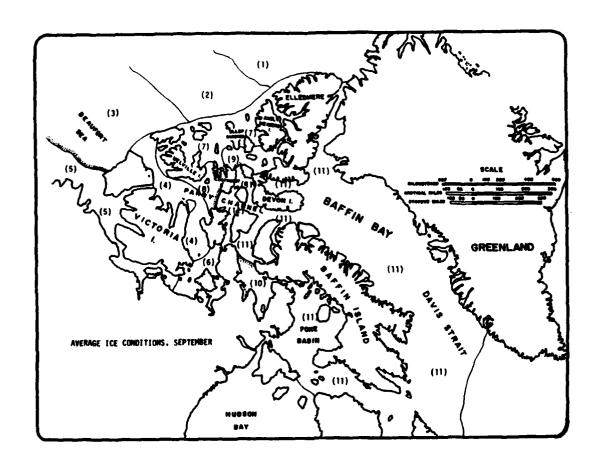
ICE AREA	CE CHARACTERISTICS
1	FY 6.2-60; NY 18-100; ice islands
2	FY 7.4-60; MY 18-110; ice islands
3	FY 6.8-40; MY 18-60; 1cm 1slands
4	31 0.9-4.5
5	FY 5.9-25.0; my 15-40
6	FY 6.3-40; MY 15-60
7	FY 5.0-40; NY 15-40
8	FY 6.5-30; MY 12.5-40
9	FY .73-25; NY 16-40
10	ri 6.5-25
11	Pr 5.8-40
12	FY 6.2-40
13	81 0.4-5.0
14	31 0.7-5.0
15	\$1 0.7-4.2; 'ceeergs
16	\$1 3.8-5.0; !cebergs
• •	:ceee*\$



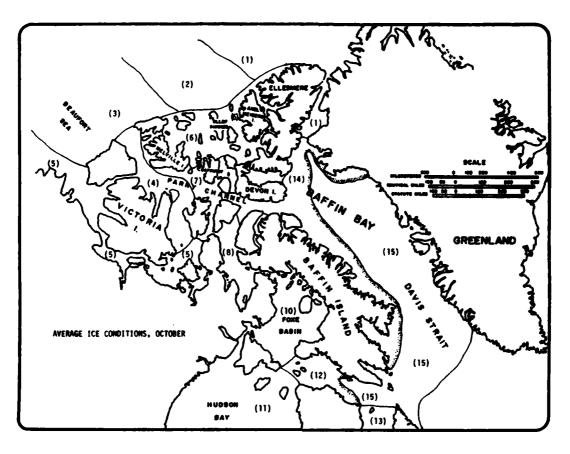
ICE AREA	ICE CHARACTERISTICS
1	FY 5.2-60; MY 18-100; Ice Islands
2	PY 6.7-60; MY 18-110; fcm islands
3	FY 5.8-40; NY 18-60; ice islands
4	\$1 0. 6- 3.0
5	FY 3.0-25; NY 15-40
6	FY 4.7-40; HY 15-60
7	FY 4.0-40; NY 15140
	PY 6.5-30; NY 12.5-42
9	FY 6.0-25; NY 16-40
10	FY 4.7-25
11	FY 4.2-40
12	91 0.8-4.0
13	81 0.5-3.5
14	BI 0.7-3.0
15	1 caborgs



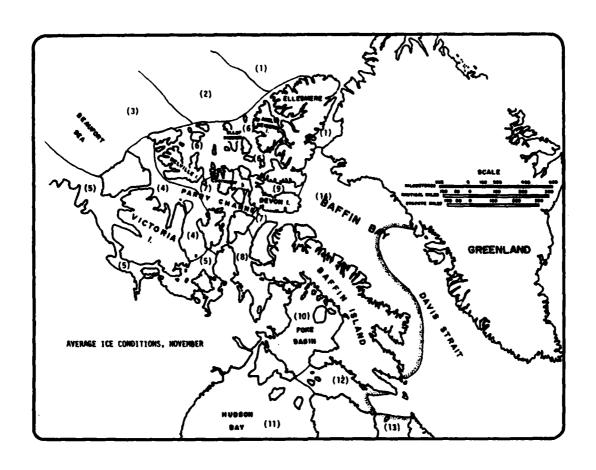
ICE AREA	ICE CHARACTERISTICS
1	FY 4.3-60; MY 16-100; fce (slands
2	FY 6.0-60; NY 16-110; 100 (slands
3	FY 5.5-40; NY 16-60; fce islands
4	8I 0.6-2.5; footergs
5	FY 2.5-40; HY 15-60
•	81 J.9-2.5; 1cecergs
7	FY 3.0-40
•	FY 3.2-30; HY 11-40
,	FY 4.0-25; NY 16-40
10	FY 2.2-40
11	91 0.6-1.S
12	[cacergs
13	31 0.5-2.0; (cobergs



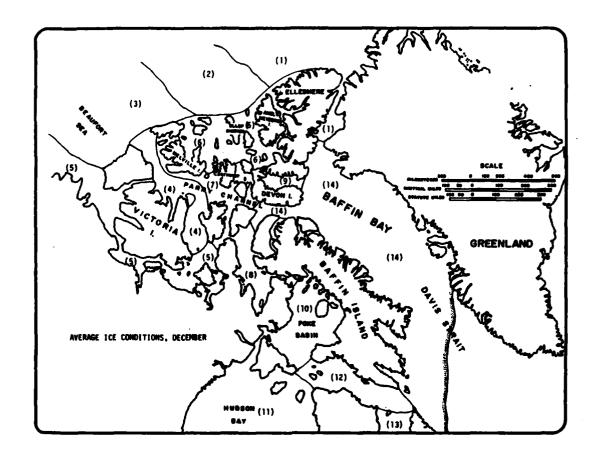
ICE AREA	ICE CHANCTERISTICS
1	FY 4.5-60; RY 16-100; (ce islands
5	FY 5.5-60; HY 16-110; ice islands
3	FY 5.2-40; NY 16-60; too islands
4	FY 2.0-40; NY 15-60
5	EE 0.3-1.0: (cotorys
6	\$1 0.6-1.5; icobergs
,	FY 2.5-25; NF 11-40
•	SE 0.8-1.7
•	\$1 0.8-3,5
10	\$1 0.8-1.5
11	[ceeergs



ICE AREA	ICE QUANCTERISTICS
1	FY 1.5-60; NY 12-100; ice (slands
2	FY 1.8-60; MY 12-110; 1ce 1slands
3	FY 1.5-40; NY 10-40; ica islands
4	PY 1.1-49; RY 10-60
5	FY 0.8-30; HY 10-40
6	FY 1.4-20; MY 10-40
7	FY 0.8-20; HT 8.5-40
•	FY 0.9-20
,	FV 1.2-20
10	FY 0.5-10; NY 12-40
11	SI 0.7-q.8
12	91 0.8-0.9
13	FY 0.7-10: 1 caserys
14	\$1 0.8-0.3; *copergs
16	10000795



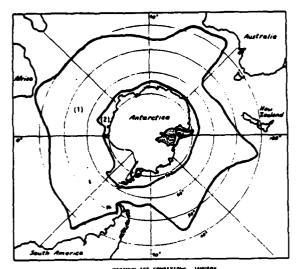
ICE AREA	ICE CHANCTERESTICS
1	FY 2.7-40; 4Y 15-100; ice islands
2	FY 2-7-60; NY 15-110; too Islands
1	PY 2.4-40; NY 15-60; too Islands
4	FY 2.2-40; IV 12-40
\$	FY 1.9-30; NY 12-40
6	FY 2.7-25: RY 12-40
,	FY 2-1-30: NY 10-40
•	PY 2.2-40
•	FY 2.4-28
10	FY 1.7-20; MY 15-40
11	PY 1.2-15
12	FV 1.4-18; icesergs
13	FY 1.0-12; icebergs
14	St 0.9-1.2: (comprys



ICE AREA	ICE CHARCTERISTICS
1	FY 3.4-60; NY 15-100; Ico Islands
2	PY 3.5-60; NY 15-110; Ice Islands
3	PY 3.1-40; NY 15-40; fcs islands
4	PY 3.0-40; NY 12-40;
5	PY 2.8-40; NY 12-40
•	FY 3.8-25; FF 12-46
7	FY 3.0-30; NY 10-40
	FY 3.2-40
•	N 1.1-28
10	FY 2.6-30; NY 15-40
11	FY 2,1-20
12	FY 2.5-25; fceedings
13	FY 2.0-25; icebargs
14	91 J.9-2.0; 1coopra

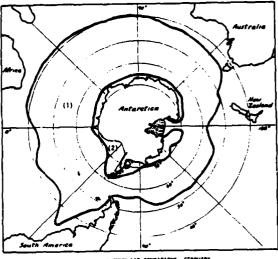
APPENDIX A.3

ANTARCTIC - MAXIMUM AND AVERAGE ICE CONDITIONS BY MONTH



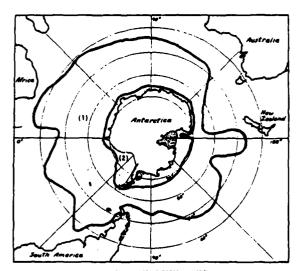
May I Lumb	ILE	COMPATITORS.	Tollament s

ICE AREA	ICE CHARACTERISTICS
1	IS, OPEN WATER
2	to, 6 FT



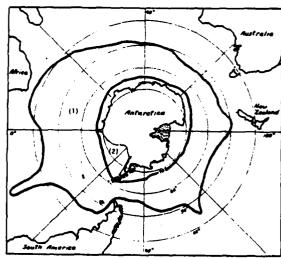
MAXIMUM ICE CONDITIONS, FEBRUARY

ICE AREA	ICE CHARACTERISTICS
1	IS. OPEN MATER
5	18, 3 FT



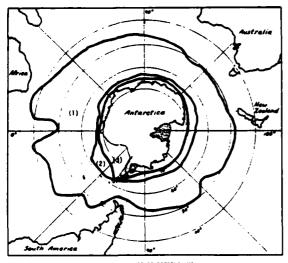
MARINUM ICE CONDITIONS, MARCH

ICE AREA	ICE CHAMCTERISTICS
1	IB, OPEN WATER
2	16, 3.5 FT



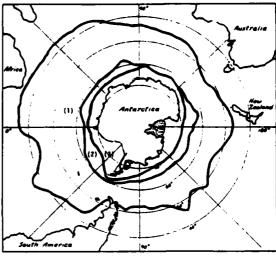
MARINUM ICE CONDITIONS, APRIL

ICE AREA	ICE CHARACTERISTICS
1.	IB, OPEN MATER
2	18, 3.5 FT



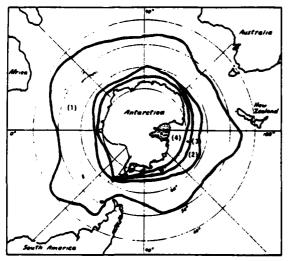
MAXIMUM ICE CONDITIONS, MAY

ICE AREA	ICE CHANCTERISTICS
1	IS, OPEN WATER
2	18, 1 27
3	18, 4 57



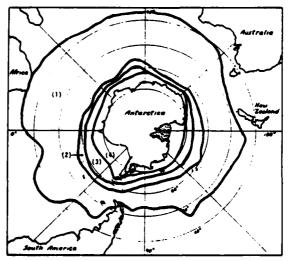
MAXIMUM ICE CONDITIONS, JUNE

ICE AREA	ICE CHARACTERISTICS
1	IB, OPEN MATER
2	18, 2 FT
3	18, 5 FT



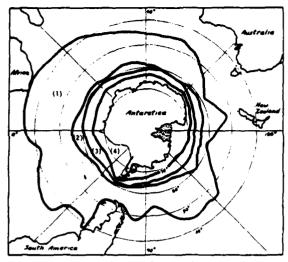
MAXIMUM ICE CONDITIONS, JULY

ICE AREA	ICE CHARACTERISTICS
1	IS, OPEN MATER
2	B, 1 FT
3	(8, 3 FT
4	18, 5 77



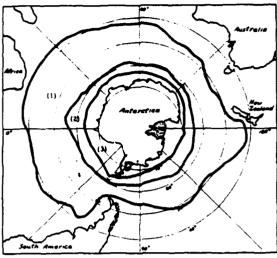
MAXIMUM ICE CONDITIONS, AUGUST

ICE AREA	ICE CHARACTERISTICS
,	IB. OPEN MATER
2	10, 2 FT
3	19, 4 77
4	18, 6 FT



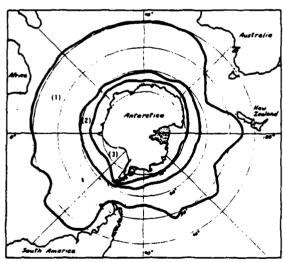
MAXIMUM ICE CONDETIONS, SEPTEMBER

ICE AREA	ICE CHARACTERISTICS	
1	IS, OPEN MATER	
2	(8, 2 FT	
3	18, 4 FT	
4	IB. 6 FT	



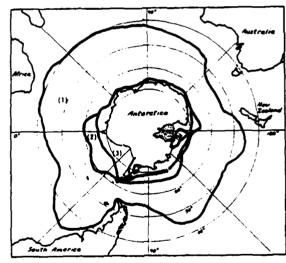
MAXIMUM ICE COMDITIONS. OCTOBER

ICE AREA	LOE CHARACTERISTICS
1	IB, OPEN WATER
2	រេ, រ ក
3	18, 6 FT



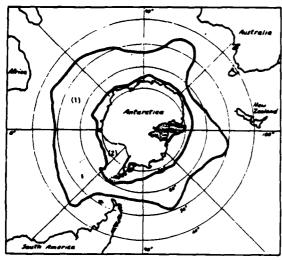
MAXIMUM ICE CONDITIONS, NOVEMBER

ICE AREA	ICE DIAMACTERISTICS
1	IS, OPER WATER
2	18, 3 77
3	(B. 6 PT



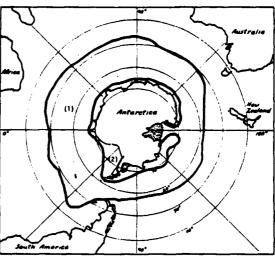
MARINUM ICE CONDITIONS, DECEMBER

ICE AREA	ICE CHAMACTERISTICS
1	IB, OPEN WATER
2	18, 3 PT
;	10.677



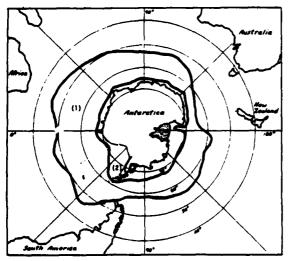
AVERAGE ICE CONDITIONS, JANUARY

ICE AREA	ICE DIAMACTERISTICS
1	IS, OPEN WATER
2	10, 6 FT



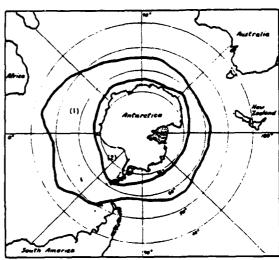
AVERAGE ICE CONDITIONS, FEBRUARY

ICE AREA	ICE CHAMCTERISTICS
1	IB. open water
2	18. 3 FT



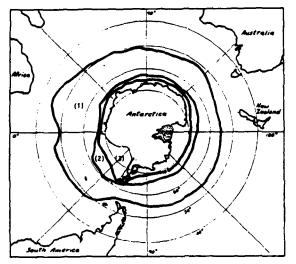
AVENUE ICE COMITIONS, NUICH

ICE MEA	ICE CHAMCTERISTICS
1	18, GPGN WATER
2	19, 3.5 FT



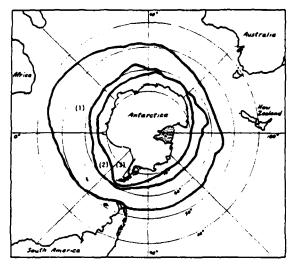
AVERAGE ICE COMPLTIONS, APRIL

ICE AREA	ICE CHARACTERISTICS
1	IB, OPEN MATER
5	18, 3,5 FT



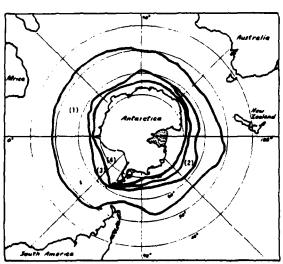
AYERAGE ICE CONDITIONS, MAY

ICE AREA	ICE QUARACTERISTICS
1	IB. OPEN MATER
2	ts, 1 FT
,	18, 4 FT



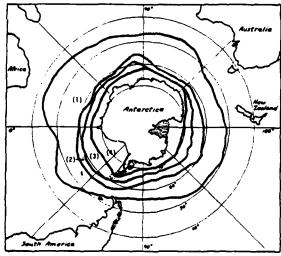
AVERAGE ICE CONDITIONS, JUNE

ICE AREA	ICE QUARACTERISTICS
1	IS, OPEN MATER
2	t8, 2 FT
3	នេ, ទ កា



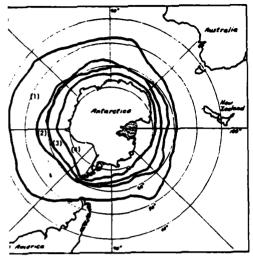
AVERAGE ICE COMDITIONS, JULY

ICE AREA	ICE CHAMACTERISTICS
1	IS. OPEN MATER
2	18, 1 97
3	19, 3 FT
•	19, 5 FT



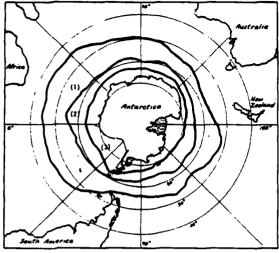
AVERAGE ICE CONDITIONS, AUGUST

ALAA EDI	ICE QUARACTERISTICS
1	IB, OPEN MATER
2	18, 2 FT
3	18, 4 FT
4	Ik, 6 FT



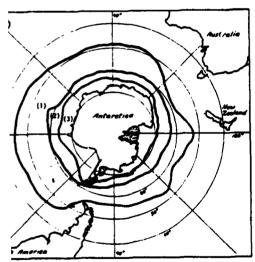
AVERAGE ICE COMPLTIONS, SEPTEMBER

E AREA	ICE CHAMACTERISTICS
1	IB. OPEN MATER
2	18, 2 FT
3	IB, 4 FT
•	IB, 6 FT



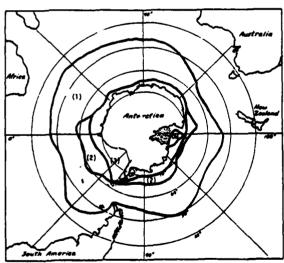
AVERAGE ICE CONDITIONS, OCTOBER

ICE AREA	ICE CHARACTERISTICS
1	IS, OPEN MATER
2	18, 3 FT
3	IB, 6 FT



AVERAGE ICE CONDITIONS, HOVERBER

AREA	ICE CHAMCTERISTICS
1	IO, OPEN WATER
2	18, 3 FT
3	18, 6 FT

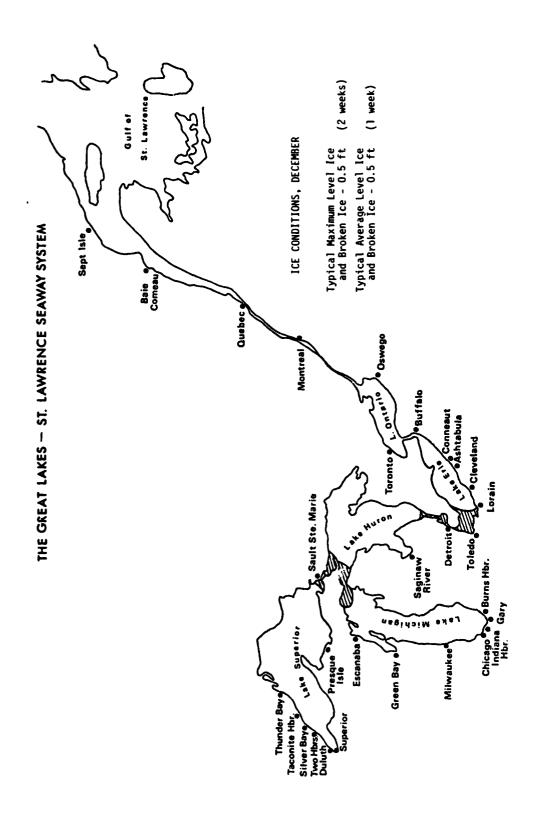


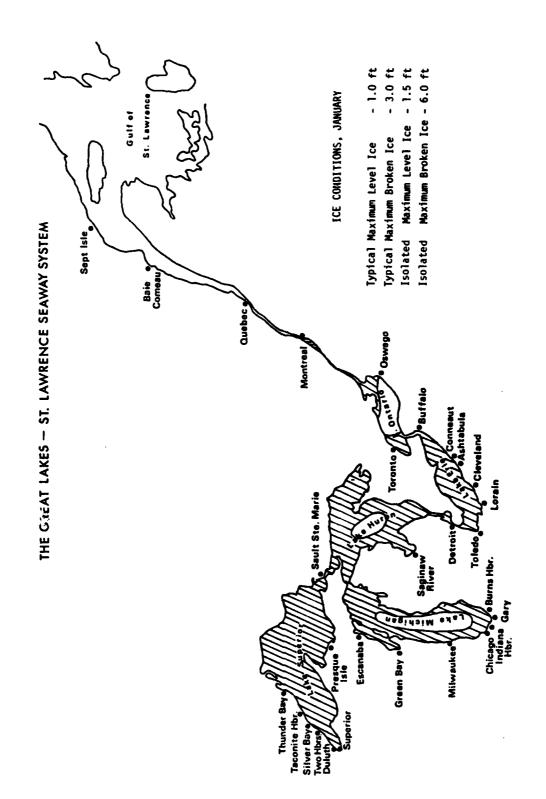
AVERAGE ICE CONDITIONS, DECEMBER

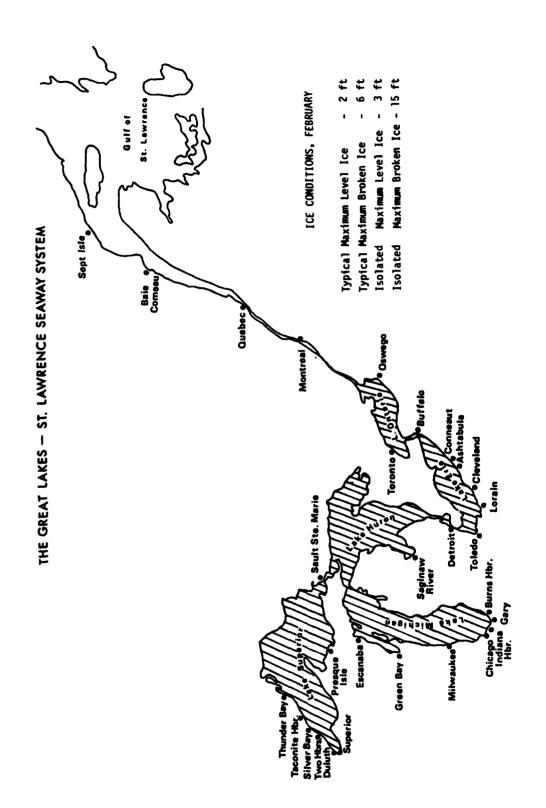
ICE AREA	ICE CHAMCTERISTICS
1	IS, OPEN MATER
2	19, 3 FT
,	18. 6 97

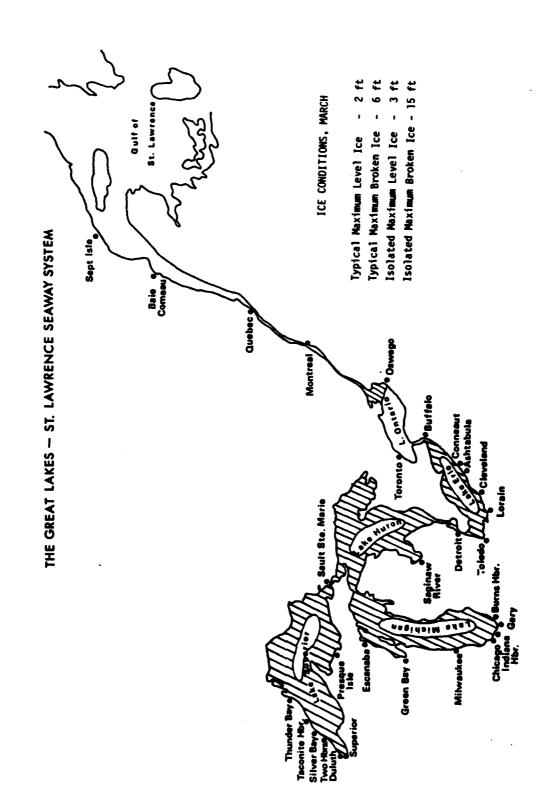
APPENDIX A.4

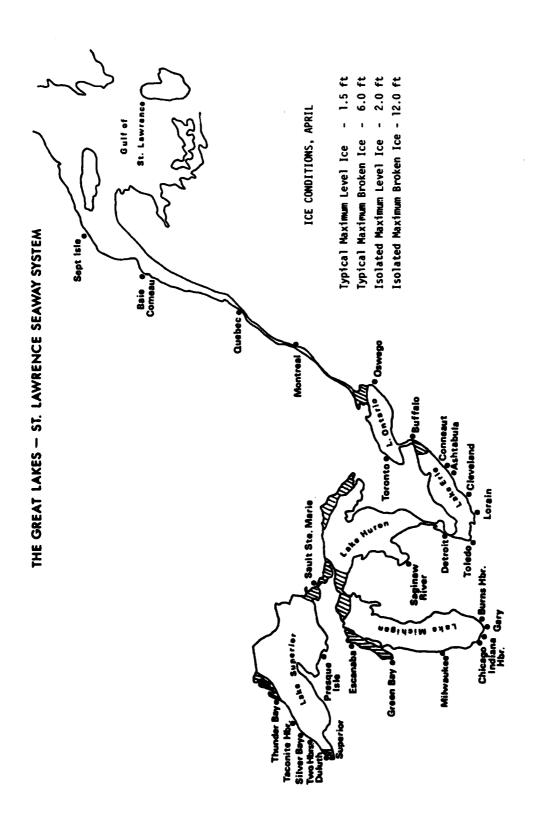
GREAT LAKES - MAXIMUM AND AVERAGE ICE CONDITIONS BY MONTH





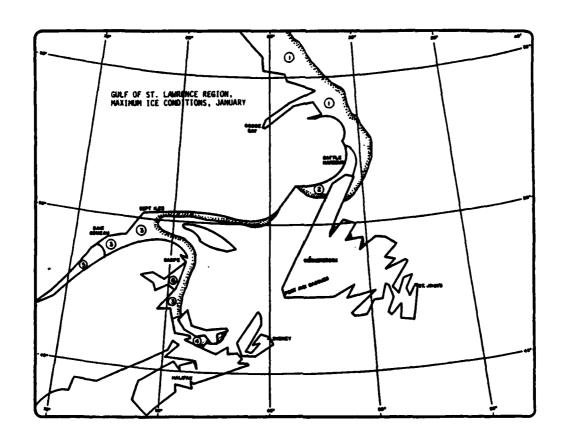






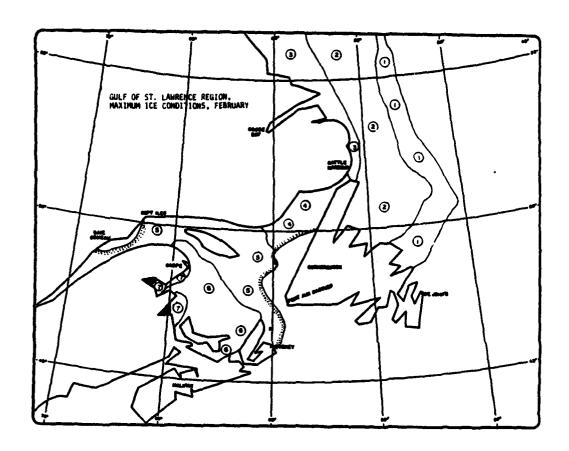
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APPENDIX A.5 GULF OF ST. LAWRENCE - MAXIMUM AND AVERAGE ICE CONDITIONS BY MONTH



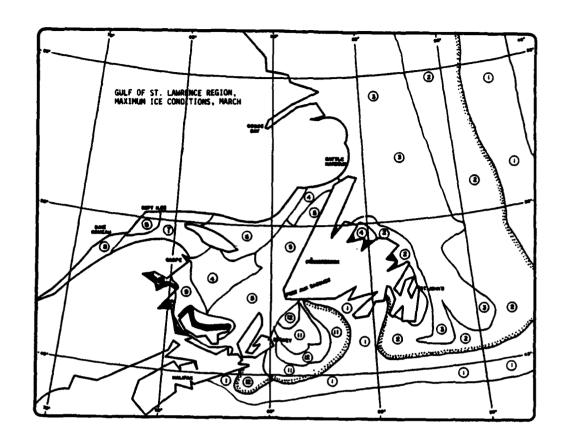
MAXIMEN ICE CONDITIONS, JANUARY

ICE AREA	ICE CHARACTERISTICS
1	FY 1.25
2	FY 0.6
3	FY 0.4
4	FY 0.2
5	FY 1.0
6	FY 1.25



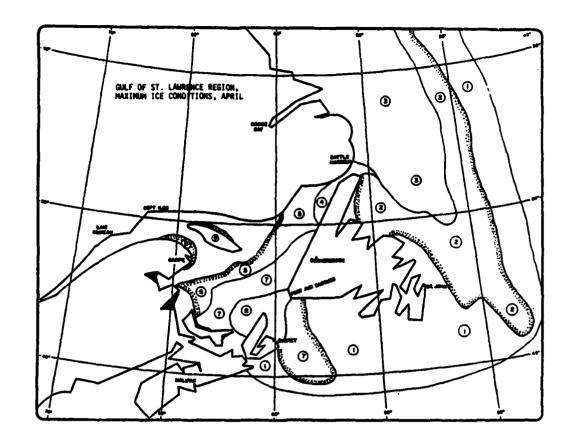
MAXIMUM ICE CONDITIONS, FEBRUARY

ICE AREA	ICE CHARACTERISTICS
, _	8I 0.6-2.5
2	FY 3.2
3	FY 1.2
4	FY 0.8
5	FY 1.0
6	FY 2.0
7	FY 2.3



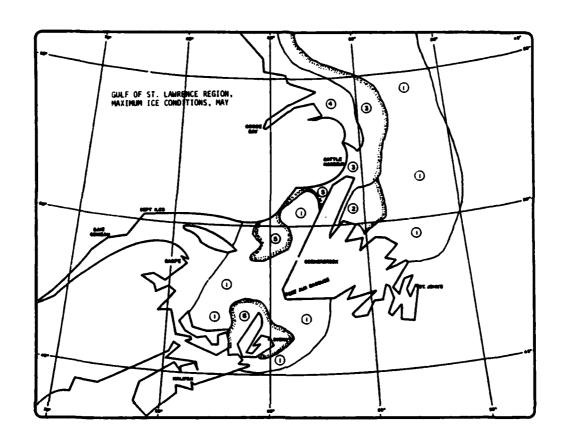
MAXIMUM ICE CONDITIONS, MARCH

ICE AREA	TOE CHARACTERISTICS
1	ICENERALS
2	81 0.8-3.0
3	PY 4.0
4	FY 2.5
5	PV 1.8
6	FY 2.8
7	rt 2.0
•	FY 2.2
•	FY 3.0
10	FY 1.2
11	81 0.8-2.2
12	91 3.4-2.2



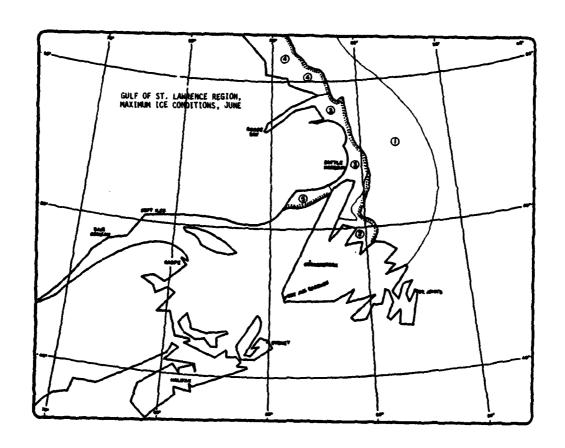
MARDING ICE COMDITIONS, APRIL

ICE AREA	. ICE CHANGTERISTICS
1	:CENEMAS
2	81 0.8-3.3
3	FY 4.2
4	FY 2.8
5	B1 0.7-2.0
•	81 0.7-1.5
7	PY 1.8
•	FY 2.0
,	St 0.6-1.8



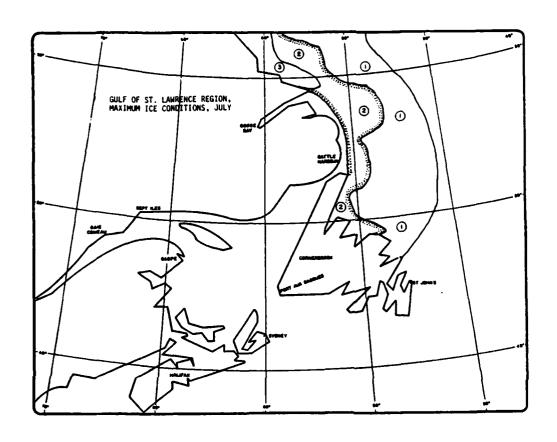
MAXIMUM ICE CONDITIONS, MAY

ICE AREA	ICE CHARACTERISTICS
1	ICEBERGS
2	81 0.4-2.0
3	FY 2.8, MY 10.0
4	FY 3.3, MY 13.0
5	BI 0.3-1.8
6	81 0.2-1.5



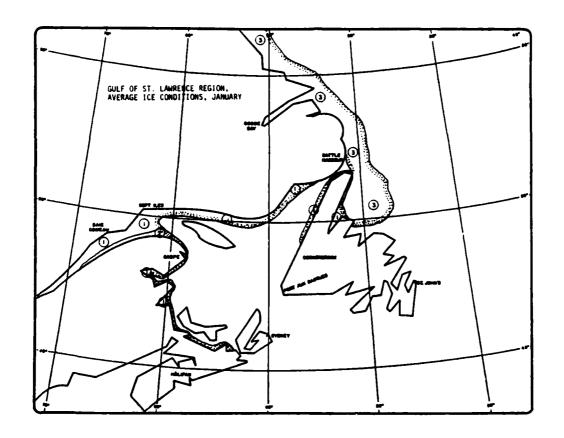
MAXIMUM ICE CONDITIONS, JUNE

ICE AREA	ICE CHAMACTERISTICS
1	ICEBERGS
2	SI 0.6-1.2
3	FY 2.0, MY 10.0
4	FY 2.2, MY 12.0
5	8I 0.3-1.0



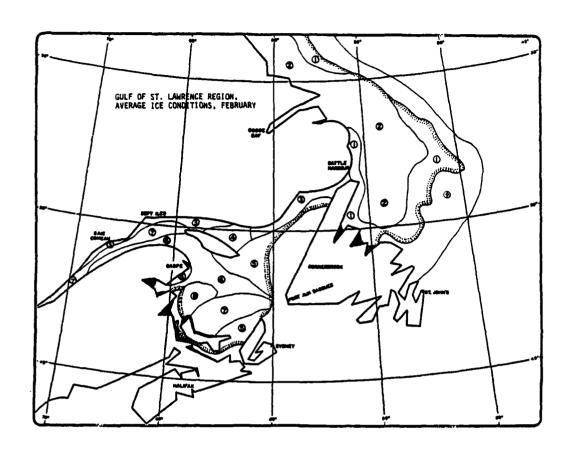
MAXIMUM ICE CONDITIONS, JULY

ICE AREA	ICE CHARACTERISTICS
1	ICEBERGS
2	81 0.2-1.0
3	FY 1.5, MY 10.0



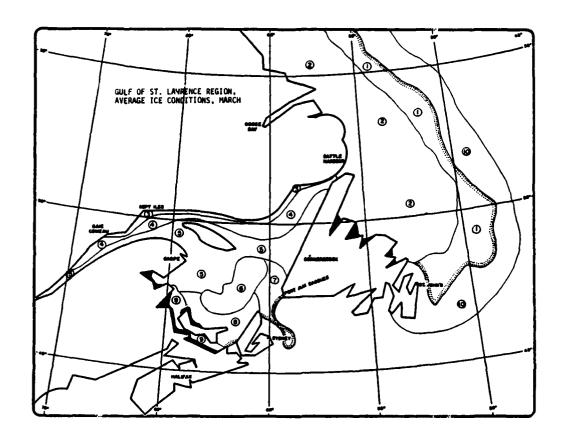
AVERAGE ICE CONDITIONS, JANUARY

ICE AREA	ICE CHARACTERISTICS
1	FY 0.5
2	FY 1.0
3	FY 1.5



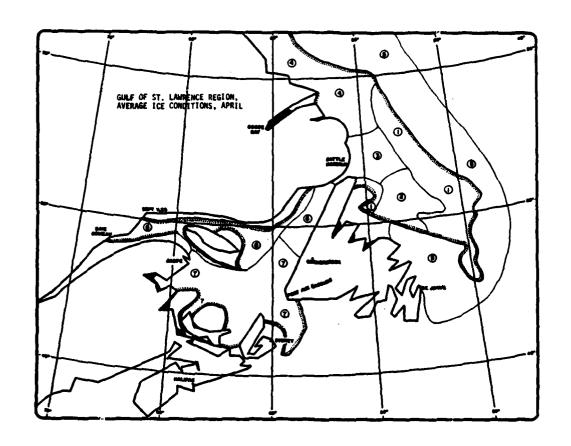
AVERAGE ICE CONDITIONS, FEBRUARY

ICE AREA	ICE CHARACTERISTICS
1	St 0.5-0.8
2	FY 2.5
3	PY 1.5
4	FV 1.8
5	81 0.7-0.1
6	PY 1.4
7	FY 1.2
8	FY 1.3
9	:ceneres



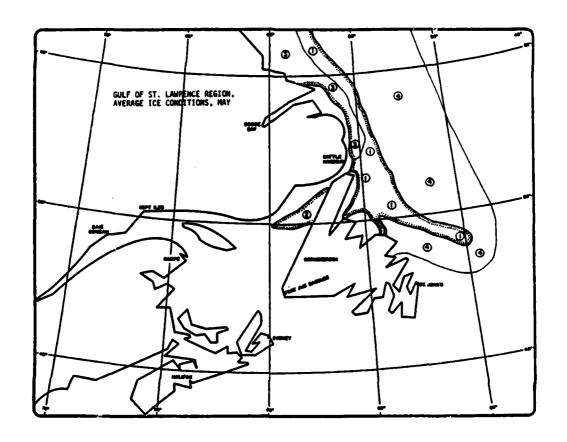
AVERAGE ICE CONDITIONS, MARCH

ICE AREA	ICE CHAMACTERISTICS
1	8I 0.6-1.5
2	FY 3.0
3	FY 0.8
4	FY 1.5
. \$	PY 2.0-12
6	FY 2.2-10
7	FY 1.0
8	FY 1.2
9	FY 1.3
10	:CEBENAS



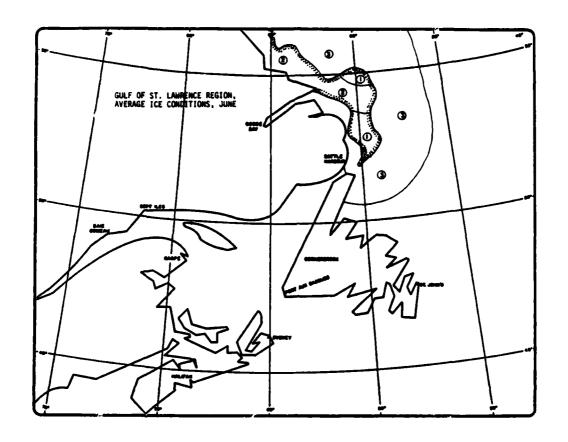
AVERAGE ICE COMPLETIONS, APRIL

ICE AREA	ICE CHANCTERISTICS
1	SI 0.3-1.8
2	PY 2.5
;	FY 2.8
•	PY 3.2
5	tcoos.
6	PY 1.6
7	81 0.8-2.0
•	BE 0.6-1.5



AVERAGE ICE CONDITIONS, MAY

ICE AREA	ICE CHARACTERISTICS
1	8I 0.5-1.0
2	BI 0.3-0.7
3	FY 3.0, HY 12.0
4	ICEBERGS

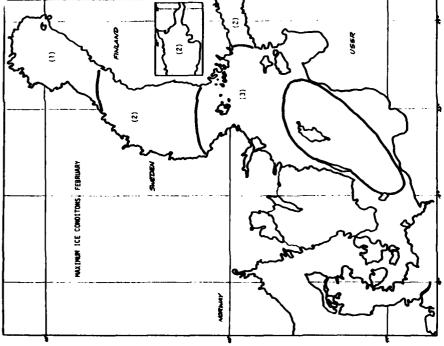


AVERAGE ICE CONDITIONS, JUNE

ICE AREA	ICE CHARACTERISTICS
1	BI 0.3-1.0
2	FY 2.0, MY 6.0
3	ICEBERGS

APPENDIX A.6

BALTIC SEA - MAXIMUM AND AVERAGE ICE CONDITIONS BY MONTH

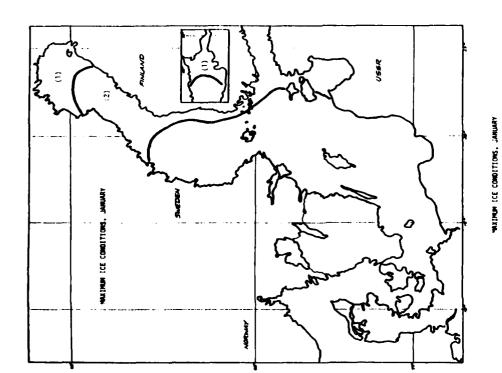




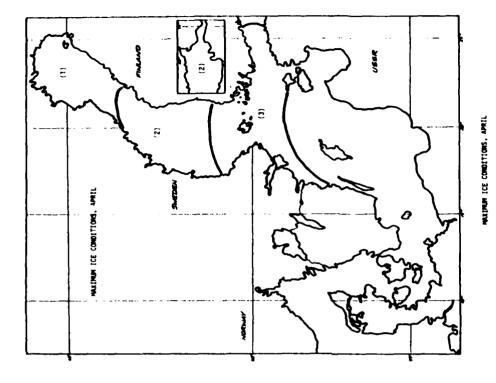
ICE CHARACTERISTICS

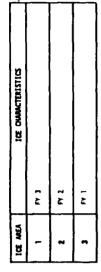
ICE AREA

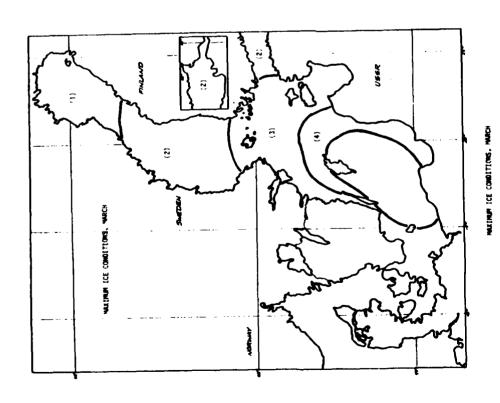
2 2 2



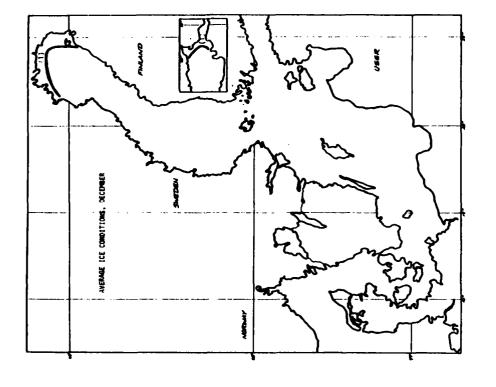
ICE AREA ICE CHARACTERISTICS

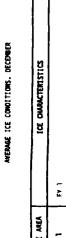


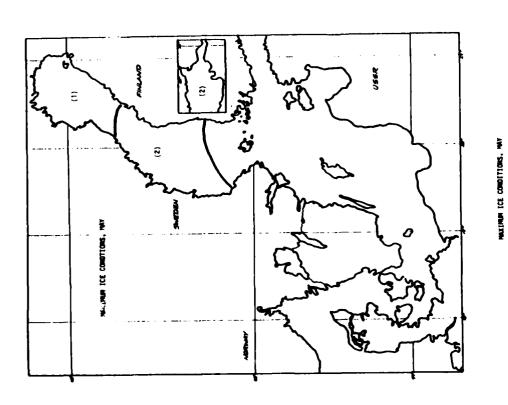


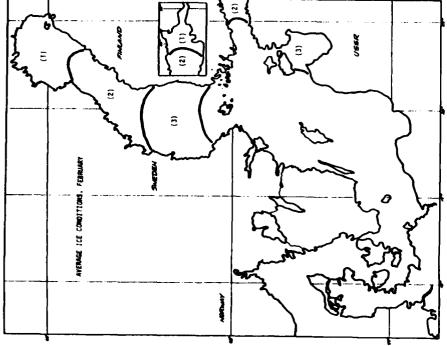


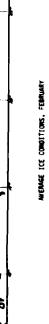
1	IG OMMCTRIISTICS
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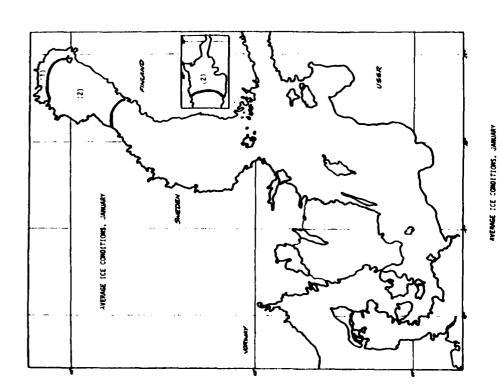


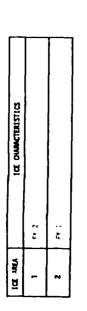


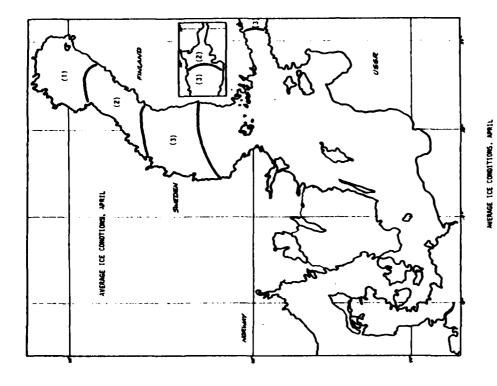


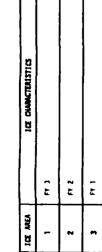


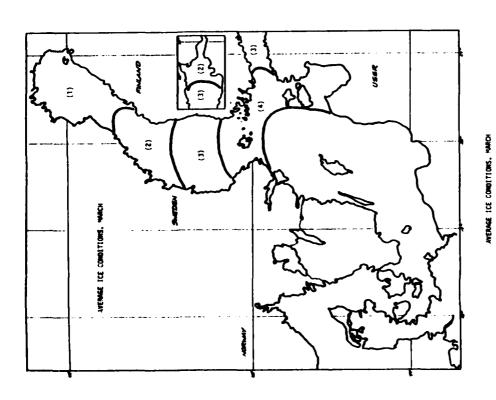












ICE AREA	ICE OMMCTERISTICS
	د ۸۶
2	FY 2
3	5·1 b4
•	ولم ا

APPENDIX A.7 WORLD METEOROLOGICAL ORGANIZATION SEA ICE NOMENCLATURE

ICE TERMS ARRANGED IN ALPHABETICAL ORDER

dge: Ridge which has undergone considerable weathering. These ridges sest described as undulations.

ice: Submerged ice attached or anchored to the bottom, irrespective of lature of its formation.

:e: Ice without snow cover.

A large feature of pack ice arrangement; longer than it is wide; from to more than 100 km in width.

vit: A large piece of floating glacier ice, generally showing less than above sea-level but more than 1 m and normally about 100-300 sq. m in area.

Situation of a vessel surrounded by ice and unable to move.

e: (see Floe).

An extensive crescent-shaped indentation in the *ice* edge, formed by er wind or current.

ce: Accumulations of *floating ice* made up of fragments not more than icross, the wreckage of other forms of ice.

:: From the point of view of the submariner, a downward projection from inderside of the *ice canopy*; the counterpart of a *hummock*.

): The breaking away of a mass of ice from an $ice\ wall$, $ice\ front$, or rg.

mack ice: Pack ice in which the concentration is 7/10 to 8/10 (6/8 to than 7/8, composed of floes mostly in contact.

ed ice edge: Close, clear-cut ice edge compacted by wind or current; ly on the windward side of an area of pack ice.

ing: Pieces of floating ice are said to be compacting when they are cted to a converging motion, which increases ice concentration and/or ces stresses which may result in ice deformation.

pack ice: Pack ice in which the concentration is 10/10 (8/8) and no is visible.

ration: The ratio in tenths of the sea surface actually covered by ice e total area of sea surface, both ice-covered and *ice-free*, at a fic location or over a defined area.

ration boundary: A line approximating the transition between two areas ck ice with distinctly different concentrations.

Consolidated pack ice: Pack ice in which the concentration is 10/10 (8/8) and the floes are frozen together.

Consolidated ridge. A ridge in which the base has frozen together.

Crack: Any fracture which has not parted.

Dark nilas: Nilas which is under 5 cm in thickness and is very dark in color.

Deformed ice: A general term for ice which has been squeezed together and in places forced upwards (and downwards). Subdivisions are rafted ice, ridged ice, and hummocked ice.

Difficult area: A general qualitative expression to indicate, in a relative manner, that the severity of ice conditions prevailing in an area is such that navigation in it is difficult.

Diffuse ice edge: Poorly defined *ice edge* limiting an area of dispersed ice; usually on the leeward side of an area of pack ice.

Diverging: *Ice fields* or *floes* in an area are subjected to diverging or dispersive motion, thus reducing ice *concentration* and/or relieving stress in the ice.

Dried ice: Sea ice from the surface of which melt-water has disappeared after the formation of cracks and thaw holes. During the period of drying, the surface whitens.

Easy area: A general qualitative expression to indicate, in a relative manner, that ice conditions prevailing in an area are such that navigation in it is not difficult.

Fast ice: Sea ice which forms and remains fast along the coast, where it is attached to the shore, to an ice wall, to an ice front, between shoals or grounded icebergs. Vertical fluctuations may be observed during changes of sea-level. Fast ice may be formed in situ from sea water or by freezing of pack ice of any age to the shore, and it may extend a few metres or several hundred kilometres from the coast. Fast ice may be more than one year old and may then be prefixed with the appropriate age category(old, second-year, or multi-year). If it is thicker than about 2 m above sea-level it is called an ice shelf.

Fast-ice boundary: The *ice* boundary at any given time between fast ice and pack ice.

Fast-ice edge: The demarcation at any given time between fast ice and open water.

Finger rafted ice: Type of rafted ice in which floes thrust "fingers" alternately over and under the other.

Finger rafting: Type of rafting whereby interlocking thrusts are formed, each floe thrusting "fingers" alternately over and under the other. Common in nilas and grey ice.

Firn: Old snow which has recrystallized into a dense material. Unlike snow, the particles are to some extent joined together; but, unlike ice, the air spaces in it still connect with each other.

First-year ice: Sea ice of not more than one winter's growth, developing from young ice; thickness 30 cm - 2 m. May be subdivided into thin first-year ice, white ice, medium first-year ice, and thick first-year ice.

Flaw: A narrow separation zone between pack ice and fast ice, where the pieces of ice are in chaotic state; it forms when pack ice shears under the effect of a strong wind or current along the fast ice boundary.

Flaw lead: A passage-way between pack ice and fast ice which is navigable by surface vessels.

Flaw polynya: A polynya between pack ice and fast ice.

Floating ice: Any form of ice found floating in water. The principal kinds of floating ice are lake ice, river ice, and sea ice, which form by the freezing of water at the surface, and glacier ice (ice of land origin) formed on land or in an ice shelf. The concept includes ice that is stranded or grounded.

Floe: Any relatively flat piece of sea ice 20 m or more across. Floes are subdivided according to horizontal extent as follows:

GIANT: Over 10 km across. VAST: 2-10 km across. BIG: 500-2,000 m across. MEDIUM: 100-500 m across. SMALL: 20-100 m across.

Floeberg: A massive piece of sea ice composed of a hummock, or a group of hummocks, frozen together and separated from any ice surroundings. It may float up to 5 m above sea-level.

Flooded ice: Sea ice which has been flooded by melt-water or river water and is heavily loaded by water and wet snow.

Fracture: Any break or rupture through very close pack ice, compact pack ice, consolidated pack ice, fast ice, or a single floe resulting from deformation processes. Fractures may contain brash ice and/or be covered with nilas and/or young ice. Length may vary from a few meters to many kilometers.

Fracture zone: An area which has a great number of fractures.

Fracturing: Pressure process whereby ice is permamently deformed, and rupture occurs. Most commonly used to describe breaking across very close pack ice, compact pack ice, and consolidated pack ice.

Frazil ice: Fine spicules or plates of ice, suspended in water.

Friendly ice: From the point of view of the submariner, an *ice canopy* containing may large *skylights* or other features which permit a submarine to surface. There must be more than ten such features per 30 nautical miles (56 km) along the submarine's track.

Frost smoke: Fog-like clouds due to contact of cold air with relatively warm water, which can appear over openings in the ice, or leeward of the *ice edge*, and which may persist while ice is forming.

Giant floe: (see Floe).

Glacier: A mass of snow and ice continuously moving from higher to lower ground or, if afloat, continuously spreading. The principal forms of glacier are: inland ice sheets, *ice shelves*, *ice streams*, ice caps, ice piedmonts, cirque glaciers, and various types of mountain (valley) glaciers.

Glacier berg: An irregularly shaped iceberg.

Glacier ice: Ice in, or originating from, a glacier, whether on land or floating on the sea as *icebergs*, bergy bits, or growlers.

Glacier tongue: Projecting seaward extenstion of a glacier, usually afloat. In the Antarctic glacier tongues may extend over many tens of kilometers.

Grease ice: A later stage of freezing than frazil ice when the crystals have coagulated to form a soupy layer on the surface. Grease ice reflects little light, giving the sea a matt appearance.

Grey ice: Young ice 10-15 cm thick. Less elastic than nilas and breaks on swell. Usually rafts under pressure.

Grey-white ice: Young ice 15-30 cm thick. Under pressure more likely to ridge than to raft.

Grounded hummock: Hummocked grounded ice formation. There are single grounded hummocks and lines (or chains) of grounded hummocks.

Grounded ice: Floating ice which is aground in shoal water.

Growler: Smaller piece of ice than α bergy bit or floeberg, often transparent but appearing green or almost black in color, extending less than 1 m above the sea surface and normally occupying an area of about 20 sq. m.

Hostile ice: From the point of view of the submariner, an *ice canopy* containing no large *skylights*.

Hummock: A hillock of broken ice which has been forced upwards by pressure. May be fresh or weathered. The submerged volume of broken ice under the hummock, forced downwards by pressure, is termed a hummock.

Hummocked ice: Sea ice piled haphazardly one piece over another to form an uneven surface. When weathered, has the appearance of smooth hillocks.

Hummocking: The pressure process by which sea ice is forced into hummocks. When the floes rotate in the process it is termed screwing.

Iceberg: A massive piece of ice of greatly varying shape, more than 5 m above sea-level, which has broken away from a glacier, and which may be afloat or aground. Icebergs may be described as tabular, dome-shaped, sloping, pinnacled, weathered, or glacier bergs.

Iceberg tongue: A major accumulation of icebergs projecting from the coast, held in place by grounding and joined together by $fast\ ice$.

Ice blink: A whitish glare on low clouds above an accumulation of distant ice.

Ice-bound: A harbor, inlet, etc., is said to be ice-bound when navigation by ships is prevented on account of ice, except possibly with the assistance of an icebreaker.

Ice boundary: The demarcation at any given time between fast ice and pack ice or between areas of pack ice of different concentrations.

Ice breccia: Ice pieces of different age frozen together.

Ice cake: Any relatively flat piece of sea ice less than 20 m across.

Ice canopy: Pack ice from the point of view of the submariner.

Ice cover: The ratio of an area of ice of any concentration to the total area of sea surface within some large geographic local; this local may be global, hemispheric, or prescribed by a specific oceanographic entity such as Baffin Bay or the Barents Sea.

Ice edge: The demarcation at any given time between the open sea and sea ice of any kind, whether fast or drifting. It may be termed compacted or diffuse.

Ice field: Area of pack ice consisting of any size of floes, which is greater than 10 km across.

Icefoot: A narrow fringe of ice attached to the coast, unmoved by tides and remaining after the $fast\ ice$ has moved away.

Ice-free: No sea ice present. There may be some ice of land origin.

Ice front: The vertical cliff forming the seaward face of an *ice shelf* or other floating *glacier* varying in height from 2-50 m or more above sealevel.

Ice island: A large piece of floating ice about 5 m above sea-level, which has broken away from an Arctic ice shelf, having a thickness of 30-50 m and an area of from a few thousand square meters to 500 sq. km or more, and usually characterized by a regularly undulating surface which gives it a ribbed appearance from the air.

Ice jam: An accumulation of broken river ice or sea ice caught in a narrow channel.

Ice keel: From the point of view of the submariner, a downward-projecting ridge on the underside of the *ice canopy*; the counterpart of a ridge. Ice keels may extend as much as 50 m below sea-level.

Ice limit: Climatological term referring to the extreme minimum or extreme maximum extent of the $ice\ edge$ in any given month or period based on observations over a number of years. Term should be preceded by minimum or maximum.

Ice massif: A concentration of sea ice covering hundreds of square kilometers, which is found in the same region every summer.

Ice of land origin: Ice formed on land or in an $ice\ shelf$, found floating in water. The concept includes, ice that is stranded or grounded.

Ice patch: An area of pack ice less than 10 km across.

Ice port: An embayment in an $ice\ front$, often of a temporary nature, where ships can moor alongside and unload directly onto the ice shelf.

Ice rind: A brittle shiny crust of ice formed on a quiet surface by direct freezing or from grease ice, usually in water of low salinity. Thickness to about 5 cm. Easily broken by wind or swell, commonly breaking in rectangular pieces.

Ice shelf: A floating ice sheet of considerable thickness showing 2-50 m or more above sea-level, attached to the coast. Usually of great horizontal extent and with a level or gently undulating surface. Nourished by annual snow accumulation and often also by the seaward extension of land glaciers. Limited areas may be aground. The seaward edge is termed an ice front.

Ice stream: Part of an inland ice sheet in which the ice flows more rapidly and not necessarily in the same direction as the surrounding ice. The margins are sometimes clearly marked by a change in direction of the surface slope but may be indistinct.

Ice under pressure: Ice in which deformation processes are actively occurring and hence a potential inpediment or danger to shipping.

Ice wall: An ice cliff forming the seaward margin of a glacier which is not afloat. An ice wall is aground, the rock basement being at or below sealevel.

Lake ice: Ice formed on a lake, regardless of observed location.

Large fracture: More than 500 m wide.

Large ice field: An ice field over 20 km across.

Lead: Any fracture or passage-way through sea ice which is navigable by surface vessels.

Level ice: Sea ice which is unaffected by deformation.

Light nilas: Nilas which is more than 5 cm in thickness and rather lighter in color than dark nilas.

Mean ice edge: Average position of the $ice\ edge$ in any given month or period based on observations over a number of years. Other terms which may be used are mean maximum ice edge and mean minimum ice edge.

Medium first-year ice: First-year ice 70-120 cm thick.

Medium floe: (see Floe).

Medium fracture: 200 to 500 m wide.

Medium ice field: An ice field 15-20 km across.

Multi-year ice: Old ice up to 3 m or more thick which has survived at least two summers' melt. Hummocks even smoother than in second-year ice, and the ice is almost salt-free. Color, where bare, is usually blue. Melt pattern consists of large interconnecting irregular puddles and a well-developed drainage system.

New ice: A general term for recently formed ice which includes frazil ice, grease ice, slush, and shuga. These types of ice are composed of ice crystals which are only weakly frozen together (if at all) and have a definite form only while they are afloat.

New ridge: *Ridge* newly formed with sharp peaks and slope of sides usually 40°. Fragments are visible from the air at low altitude.

Nilas: A thin elastic crust of ice, easily bending on waves and swell and under pressure, thrusting in a pattern of interlocking "fingers" (finger rafting). Has a matt surface and is up to 10 cm in thickness. May be subdivided into dark nilas and light nilas.

Nip: Ice is said to nip when it forcibly presses against a ship. A vessel so caught, though undamaged, is said to have been nipped.

Old ice: Sea ice which has survived at least one summer's melt. Most topographic features are smoother than on first-year ice. May be subdivided into second-year ice and multi-year ice.

Open pack ice: Pack ice in which the ice concentration is 4/10 to 6/10 (3/8 to less than 6/8) with many leads and polynyas, and the floes are generally not in contact with one another.

Open water: A large area of freely navigable water in which sea ice is present in concentrations less than 1/10 (1/8). When there is no sea ice present, the area should be termed ice-free, even though icebergs are present.

Pack ice: Term used in a wide sense to include any area of sea ice, other than fast ice, no matter what from it takes or how it is disposed.

Pancake ice: Predominantly circular pieces of ice from 30 cm - 3 m in diameter, and up to about 10 cm in thickness, with raised rims due to the pieces striking against one another. It may be formed on a slight swell from grease ice, shuga or slush or as a result of the breaking of ice rind, nilas or, under severe conditions of swell or waves, of grey ice. It also sometimes forms at some depth, at an interface between water bodies of different physical characteristics, from where it floats to the surface; its appearance may rapidly cover wide areas of water.

Polynya: Any non-linear shaped opening enclosed in ice. Polynyas may contain brash ice and/or be covered with new ice, nilas or young ice; submariners refer to these as skylights. Sometines the polynya is limited on one side by the coast and is called a shore polynya or by fast ice and is called a flaw polynya. If it recurs in the same position every year, it is called a recurring polynya.

Puddle: An accumulation on ice of melt-water, mainly due to melting snow, but in the more advanced stages also to the melting of ice. Initial stage consists of patches of melted snow.

Rafted ice: Type of deformed ice formed by one piece of ice overriding another.

Rafting: Pressure processes whereby one piece of ice overrides another. Most common in new and young ice.

Ram: An underwater ice projection from an *ice wall*, *ice front*, *iceberg*, or *floe*. Its formation is usually due to a more intensive melting and erosion of the unsubmerged part.

Recurring polynya: A polynya which recurs in the same position every year.

Ridge: A line or wall of broken ice forced up by pressure. May be fresh or weathered. The submerged volume of broken ice under a ridge, forced downwards by pressure, is termed an ice keel.

Ridged ice: Ice piled hapharzardly one piece over another in the form of ridges or walls. Usually found in first-year ice.

Ridged-ice zone: An area in which much ridged ice with similar characteristics has formed.

Ridging: The pressure process by which exa ice is forced into ridges.

River ice: Ice formed on a river, regardless of observed location.

Rotten ice: Sea ice which has become honeycombed and which is in an advanced state of disintegration.

Sastrugi: Sharp, irregular ridges formed on a snow surface by wind erosion and deposition. On mobile *floating ice* the ridges are parallel to the direction of the prevailing wind at the time they were formed.

Sea ice: Any form of ice found at sea which has originated from the freezing of sea water.

Second-year ice: Old ice which has survived only one summer's melt. Because it is thicker and less dense than first-year ice, it stands higher out of the water. In contrast to multi-year ice, summer melting produces a regular pattern of numerous small puddles. Bare patches and puddles are usually greenish-blue.

Shearing: An area of pack ice is subject to shear when the ice motion varies significantly in the direction normal to the motion, subjecting the ice to rotational forces. These forces may result in phenomena similar to a flaw.

Shore lead: A lead between pack ice and the shore or between pack ice and an ice front.

Shore polynya: A polynya between pack ice and the coast or between pack ice and an ice front.

Shuga: An accumulation of spongy white ice lumps, a few centimeters across; they are formed from grease ice or slush and sometimes from anchor ice rising to the surface.

Skylight: From the point of view of the submariner, thin places in the *ice canopy*, usually less than 1 m thick and appearing from below as relatively light, translucent patches in dark surroundings. The under-surface of a skylight is normally flat. Skylights are called large if big enough for a submarine to attempt to surface through them (120 m), or small if not.

Slush: Snow which is saturated and mixed with water on land or ice surfaces, or as a viscous floating mass in water after a heavy snowfall.

Small floe: (see Floe).

Small fracture: 50 to 200 m wide.

Small ice cake: An ice cake less than 2 m across.

Small ice field: An ice field 10-15 km across.

Snow-covered ice: Ice covered with snow.

Snowdrift: An accumulation of wind-blown snow deposited in the lee of obstructions or heaped by wind eddies. A crescent-shaped snowdrift, with ends pointing down-wind, is known as a snow barchan.

Standing floe: A separate floe standing vertically or inclined and enclosed by rather smooth ice.

Stranded ice: Ice which has been floating and has been deposited on the shore by retreating high water.

Strip: Long narrow area of pack ice, about 1 km or less in width, usually composed of small fragments detached from the main mass of ice, and run together under the influence of wind, swell, or current.

Tabular berg: A flat-topped *iceberg*. Most tabular bergs form by *calving* from an *ice shelf* and show horizontal banding.

Thaw holes: Vertical holes in sea ice formed when surface puddles melt through to the underlying water.

Thick first-year ice: First-year ice 30-70 cm thick.

Tide crack: Crack at the line of junction between an immovable ice foot or ice wall and fast ice, the latter subject to rise and fall of the tide.

Tongue: A projection of the ice edge up to several kilometers in length, caused by wind or current.

Vast floe: (see Floe).

Very close pack ice: Pack ice in which the concentration is 9/10 to less than 10/10 (7/8 to less than 8/8).

Very open pack ice: Pack ice in which the concentration is 1/10 to 3/10 (1/8 to less than 3/8) and water preponderates over ice.

Very small fracture: 0 to 50 m wide.

Very weathered ridge: *Ridge* with tops very rounded, slope of sides usually 20° - 30°.

Water sky: Dark streaks on the underside of low clouds, indicating the presence of water features in the vicinity of sea ice.

Weathered ridge: *Ridge* with peaks slightly rounded and slope of sides usually 30° to 40°. Individual fragments are not discernible.

Weathering: Processes of ablation and accumulation which gradually eliminate irregularities in an ice surface.

White ice: See Thin first-year ice.

Young coastal ice: The initial stage of fast ice formation consisting of nilas or young ice, its width varying from a few meters up to 100-200 m from the shoreline.

Young ice: Ice in the transition stage between nilas and first-year ice, 10-30 cm in thickness. May be subdivided into grey ice and grey-white ice.

APPENDIX B

CALCULATED ICE STRENGTHENED SCANTLINGS FOR THREE REPRESENTATIVE SHIPS

Abbreviations used in this Appendix are as follows:

MS = Mild steel

HTS = Higher strength steel

ASTM = American Society for Testing and Materials

USCG = United States Coast Guard

ABS = American Bureau of Shipping

LR = Lloyd's Register of Shipping (British)

DNV = Det Norske Veritas (Norwegian)

BV = Bureau Veritas (French)

NKK = Nippon Kaiji Kyokoi (Japanese)

GL = Germanisscher Lloyd (German)

TABLE B-1.1

ABS STRENGTHENING FOR NAVIGATION IN ICE

		Plating Thick. (in)	0.50	0.46	0.40*	0.83	0.72	0.59	0.41*	
	- -	Frame S.M. (in³)	5.8	5.8	5.8	9.61	14.4	9.0	3.8	
	AFT	Frame Spacing (in)	12.9	25.8	25.8	25.8	25.8	25.8	25.8	
		P (psi)	NA	NA N	N N	89.5	65.5	41.0	17.1	····
_		Plating Thick. (in)	0°20	0.60-0.46	0.40	96.0	98.0	0.72	0.54	
<u>ال</u> ا	HIP	Frame S.M. (in³)	5.8	5.8	5.8	6.92	21.5	14.4	7.5	
POLAR STAR	MIDSHIP	Frame Spacing (in)	12.9	25.8	25.8	25.8	25.8	25.8	25.8	
		P (psi)	NA	NA	NA	122.5	0.86	65.5	34.1	
•		Plating Thick. (in)	09.0	09.0	0.50	1.26	1.24	1.18	1.11	
	ARD	Frame S.M. (in³)	5.8	5.8	5.8 w/ 4.4 inter	51.4	46.8	42.1	37.5	
	FORWARD	Frame Spacing (in)	12.9	12.9	12.9	25.8	25.8	25.8	25.8	
		(psi)	NA	NA NA	N N	234.5	213.5	192.0	171.0	
_		Ice	A	В	ပ	IAA	ΙA	18	21	

Y = 50,000 psi

Note: Classes IAA, IA, IB, & IC are identical to the Finnish-Swedish Regulations for Navigation in Ice.

^{*} Minimum should probably be equal to rule value of 0.42.

TABLE B-1.1 (Continued)
LLOYD'S STRENGTHENING FOR
NAVIGATION IN ICE

POLAR STAR

!	Plating Thick. (in)	0.55	0.50	95.0	0.42		1	1	↑	↑
	Frame P S.M. T (in³)	5.8	5.8	5.8	5.8					
AFT	Frame Spacing (in)	12.9	12.9	25.8	25.8					
	<i>P</i> (psi)	NA	AA	AA	A A					
	Plating Thick. (in)	0.55	0.50	0.56	0.40					
HIP	Frame S.M. (in³)	5.8	5.8	5.8	5.8		as ABS IAA	ABS IA	ABS 1B	ABS IC
MIDSHIP	Frame Spacing (in)	12.9	12.9	25.8	25.8		Same as	Same as	Same as	Same as ABS
	(psi)	NA	N N	NA	NA					
	Plating Thick. (in)	1.25	0.52	0.52	0.50					
IARD	Frame S.M. (in³)	5.8	5.8	5.8	5.8 w/ 2.9-4.6	inter				
FORWARD	Frame Spacing (in)	12.9	12.9	12.9	12.9					
	(psi)	NA	¥	AN	N			ļ		<u> </u>
	Ice	*	_	2	m		IA Super	IA	18	10

TABLE B-1.1 (Continued)

CANADIAN ASPPR STRENGTHENING FOR NAVIGATION IN ICE POLAR STAR¹

		Plating Thick. (in)	0.77 (0.48)	1,39 (0.86)	1.72 (1.07)	1.98 (1.23)	2.20 (1.37)	2.36 (1.46)	2.49 (1.55)	2.66 (1.65)	2.66 (1.65)
	Į.	Frame S.M. (in³)	21.9 (13.6)	71.2 (44.2)	109.6 (68.0)	144.7 (89.7)	179.7 (1111.5)	206.0 (127.8)	230.2 (142.7)	263.0 (163.1)	263.0 (163.1)
	AFT	Frame Spacing (in)	25.8 (16.0)								→
_		<i>Р</i> (psi)	100	325	200	099	820	940	1050	1200	1200
		Plating Thick. (in)	0.77 (0.48)	1.24 (0.77)	1.54 (0.95)	1.77 (1.10)	1.98 (1.23)	2.11 (1.31)	2.24 (1.39)	2.37 (1.47)	2.37 (1.47)
AR 1	HIP	Frame S.M. (in³)	21.9 (13.6)	57.0 (35.3)	87.7 (54.4)	116.2 (72.0)	144.7 (89.7)	164.4 (102.0)	186.3 (115.5)	208.2 (129.1)	208.2 (129.1)
POLAR STAR	MIDSHIP	Frame Spacing (in)	25.8 (16.0)								
		(psi)	100	260	400	530	099	750	850	950	950
		Plating Thick. (in)	1.22 (0.75)2	1.54 (0.95)	1.88	2.18 (1.35)	2.43 (1.51)	2.66 (1.65)	2.88 (1.78)	2.98 (1.85)	2.98 (1.85)
	FORWARD	Frame S.M. (in³)	54.8 (34.0) ²	87.7 (54.4)	131.5 (81.6)	175.4 (108.8)	219.2 (135.9)	263.0 (163.1)	306.9 (190.3)	328.8 (203.9)	328.8 (203.9)
	FOR	Frame Spacing (in)	25.8 (16.0) ²								
		(psi)	250	400	009	800	1000	1200	1400	1500	1500
_		Ice		Αſ	2	ю	4	9	7	∞	10

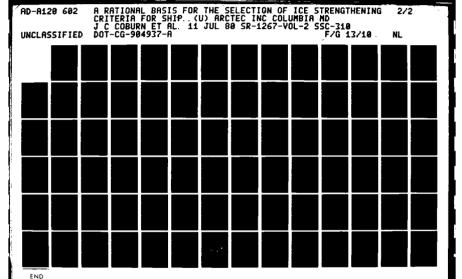
1.Assuming no waste stowed in contact with shell. 2.Scantlings for alternate frame spacing.

NOTE: Yield stress assumed to be 50,000 psi.

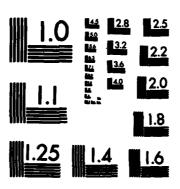
DET NORSKE VERITAS STRENGTHENING FOR NAVIGATION IN ICE POLAR STAR

	RWARD MIDSHIP	Frame Plating Frame Frame Plating Frame Frame Plating S.M. Thick. P Spacing S.M. Thick. P Spacing S.M. Thick. (in) (in) (in) (in) (in)	13.5- 0.69 1.3	ame as ABS IAA	ame as ABS IA		ame as ABS IC	27.5 1.38 N/A 16.3 27.5 1.11 N/A 16.3 27.5	34.4 1.79 N/A 16.3 34.4 1.44 N/A 16.3
	FORWARD	Frame Spacing (in)	12.0	Same as ABS	Same as ABS	Same as ABS	Same as ABS	16.3	16.3 34.4
_		$\begin{array}{c c} \operatorname{Ice} & & \\ \operatorname{Class} & & P \\ \hline & (\operatorname{psi}) \end{array}$	ICEC* N/A	IA*	IA	18	IC	: ebreaker N/A	Arctic Fredker

and material should not exceed ABS IC.



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TABLE B-1.1 (Continued)

BUREAU VERITAS STRENGTHENING FOR NAVIGATION IN ICE POLAR STAR*

		FORWARD	IRD			MIDSHIP	HIP			AFT	F	
P (psi	_	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	$\frac{P}{(psi)}$	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	$\frac{p}{(psi)}$	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)
N/A	<	12.9	11.6-	1.26	N/A	12.9	5.8	1.26	N/A	12.9	11.6- 5.8	1.26
N/A	Ø	12.9	11.6- 5.8	09.0	N/A	12.9	5.8	0.48	N/A	12.9	11.6- 5.8	0.48
N/A	¥	12.9	11.6- 5.8	0.60	N/A	25.8	5.8	0.46	A/A	25.8	5.8	0.46
Ž	N/A	12.9	5.8- 4.35	0.50	N/A	25.8	5.8	0.40	N/A	25.8	5.8	0.45
		Same	Same as ABS IAA	IAA								
		Same	as ABS IA	IA								
		Same	as ABS	18								
		Same	Same as ABS	21								

* Rule scantlings are from ABS.

TABLE B-1.1 (Continued)
NIPPON KAIJI KYOKAI
STRENGTHENING FOR NAVIGATION IN ICE

FORWARD	Frame Frame Frame Plating Frame Plating Frame Frame Plating Sacing S.M. Thick. P Spacing S.M. Thick. (in) (in) (in) (in) (in) (in)	57.1 1.31-	16.0 38.1 1.10- N/A 16.0 18.7 0.79 N/A 16.0 38.1 0.95- 0.92 0.79	16.0 26.0 1.10- N/A 25.8 5.8 0.69 N/A 16.0 26.0 0.69- 0.92 0.57	16.0 12.1 0.95- N/A 25.8 5.8 0.67 N/A 16.0 12.1 0.42 0.79	Same as ABS IAA	Same as ABS IA	Same as ABS IB	Same as ABS IC	
FORWARD	Plating Thick. (in)	16.0 57.1 1.31- 1.09	38.1 1.10- 0.92	26.0 1.10-	0.95-		as ABS	as ABS		
	Ice Glass	Ą	V	æ	ပ	IA-Super	IA	18	21	

V = 18 knots

TABLE B-1.1 (Continued)

USSR REGISTER OF SHIPPING STRENGTHENING FOR NAVIGATION IN ICE POLAR STAR

-		FORWARD	88			MIDSHIP	HIP			AFT		
Ice	P (psi)	Frame Spacing (in)	Frame S.M.	Plating Thick. (in)	P (psf)	Frame Spacing (in)	Frame S.M. (in)	Plating Thick. (in)	Р (ps1)	Frame Spacing (in)	Frame S.M. (in)	Plating Thick. (in)
¥V¥					Each V	essel Cons	sidered	Each Vessel Considered Separately	 			1
X	273	12.9	15.6	0.71	129	12.9	10.1	0.54	129	12.9	10.1	0.54
V	162	12.9	7.2	0.60	66	12.9	6.3	0.50	66	12.9	6.3	0.50
V2	N/A	12.9	5.8	0.60	N/A	25.8	5.8	0.46	N/A	25.8	7.0- 5.8	0.46
N3	N/A	12.9	5.8 -8.4	0.50	×	25.8	8	0.40	N/A	25.8	5. 8.	0.42
V4	N/A	15.5	2.8	0.50	×	25.8	8	0.40	N/A	25.8	5.8	0.42
				·								

 $\sigma_{\underline{Y}}$ = 50,000 psi

Note: Rule scantlings are from ABS.

TABLE B-1.1 (Continued)

REGISTER OF THE PEOPLES REPUBLIC OF CHINA

	_			-	[۵	POLAR STAR*	*	_	_			
		5	FORMARD			MIDSHIP	HIP			AFT	-	
Ice Class	(ps1)	Frame Spacing (in)	Frame g S.M. (in³)	Plating Thick. (in)	(psi)	Frame Frame Spacing S.M. (in) (in ³)	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame Plating S.M. Thick. (in³) (in)	Plating Thick. (in)
*18	¥	12.9	11.6	0.72	¥	12.9	5.8	0.56	¥	12.9	11.6	0.50
BI	≨	12.9	11.6	09.0	¥	12.9	5.8	0.50	¥	12.9	11.6	0.48
BII	≨	12.9	11.6	0.56	¥	25.8	5.8	0.46	¥	25.8	5.8	0.44
BIII	≨	12.9	5.8	0.50	¥	25.8	5.8	0.40	¥	25.8	ა. გ	0.45
æ	₹	12.9 5.8-	5.8-1.7	0.55	¥	25.8	5.8	0.40	HA	25.8	5.8	0.45
(River Vessels)												

*Rule scantlings are from ABS.

TABLE B-1.2

STORES - STORESTORE - PUBLICANIE

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ABS STRENGTHENING FOR NAVIGATION IN ICE

_	_			-		M.V. ARCTIC	2]					
		FORI	FORWARD			MIDSHIP	HIP			AFT	-	
Ice	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	(psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)
⋖	\$	16.5	116.9	1.00	Ş	16.5	116.9 0.84	0.84	ĄN	ار ب	116.9	88 0
. co	¥	16.5	116.9		¥	32.9	116.9 1	116.9 1.00-0.77	ž	30.00	116.9	7.7
ပ	¥		116.9 w/ 0.84	, 0.84	A	32.9	116.9	0.67	≨	32.9	116.9	0.67
IA I	234.5		37.7 inter 234.2	1.57	122.5	32.9	122.3	1.16	89.5	32.9	80	00
IA	213.5	32.9	213.2	1.50	98.0	32.9	97.9*		65.5	32.9	65.4*	0.87
18	192.0	32.9	141.8	1.43	65.5	32.9	65.9 *	0.87	41.0	32.9	41.0*	0.70
21	171.0	32.9	170.8	1.35	34.1	32.9	32.9*	0.65***	17.1	32.9	17.1*	0.48**
	_											

Y = 50,000 psi

*** Minimum should probably be equal to rule value of 0.67.
** Minimum should probably be equal to rule value of 0.60
* Minimum S.M. should probably be equal to rule value of 116.9.

TABLE B-1.2 (Continued)

LLOYD'S STRENGTHENING FOR NAVIGATION IN ICE M.V. ARCTIC

Plating Frame Frame Thick. (in) (psi) (in) (in) (in) (in) (in) (in) (in) (i		_				•1		2					
Frame Frame Plating Frame Frame Plating Frame Frame Plating S.M. Thick. (psi) (in) (in³) (in³) (in) (in³) (in) (in³) (in) (in³) (in²) (in) (in³) (in²) (in			FOR	WARD			MIDS	нгр			AF	_	
NA 16.5 116.9 1.25 NA 16.5 116.9 0.75 NA 16.5 116.9 NA 16.5 116.9 0.80 NA 32.9 116.9 0.67 NA 32.9 116.9 NA 16.5 116.9 W/ 0.67 NA 32.9 116.9 0.67 NA 32.9 116.9 NA 16.5 186.9 W/ 0.67 NA 32.9 116.9 0.67 NA 32.9 116.9 Same as ABS IA Same as ABS IA Same as ABS IC Same as ABS IC	Ice Class		Frame Spacing (in)	Fram S.M. (in ³	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	(psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)
NA 16.5 116.9 0.80 NA 16.5 116.9 0.67 NA 16.5 116.9 NA 16.5 116.9 0.80 NA 32.9 116.9 0.87 NA 32.9 116.9 NA 16.5 116.9 W/ 0.67 NA 32.9 116.9 0.67 NA 32.9 116.9 inter Same as ABS IA Same as ABS IA Same as ABS IC Same as ABS IC	*	¥	16.5		1.25	¥	16.5	116.9	0.75	AN	16.5	116.9	0.67
NA 16.5 116.9 0.80 NA 32.9 116.9 0.87 NA 32.9 116.9 NA 16.5 116.9 w/ 0.67 NA 32.9 116.9 Same as ABS IA Same as ABS IB Same as ABS IC Same as ABS IC	_	ş	16.5		0.80	¥	16.5	116.9	0.67	¥	16.5	116.9	0.67
NA 16.9 w/ 0.67 NA 32.9 116.9 0.67 NA 32.9 116.9 58.5-93.5 inter Same as ABS IA Same as ABS IB Same as ABS IC	2	¥	16.5		0.80	¥	32.9	116.9	0.87	¥	32.9	116.9	0.87
Same as Same a	ო	\$		116.9 w/ 58.5-93.5 inter	0.67	¥	32.9	116.9	0.67	¥.	32.9	116.9	0.60
Same as the same a	Super	<u> </u>					- Same as	ABS IAA					1
Ame as ABS Ame as ABS Ame as ABS	IA	<u> </u>						ABS IA					1
Same as	18	<u> </u>					àS	ABS					1
	21	<u> </u>					· Same as	ABS IC					1

TABLE B-1.2 (Continued)

CANADIAN ASPPR STRENGTHENING FOR NAVIGATION IN ICE MV ARCTIC1

-				-	•	OT LOW	:	_				
		FORWARD	IARD			MIDSHIP	HIP			AFT	—	
Ice Class	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	(psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)
-	250	32.9 (16.5)³	249.7 (125.2)³	7 1.55 2)³ (0.78)³	001	32.9 (16.5)	99.9 ² (50.1)	0.98	001	32.9 (16.5)	99.9 ² (50.1)	0.98 (0.49)
JA .	400		399.5 (200.4)	1.96 (0.98)	100		99.92	0.98	325		324.6 (162.8)	1.77 (0.88)
2	. 009		599.2 (300.5)	2.40 (1.20)	260		259.7 (130.2)	1.58 (0.79)	200		499.4 (250.4)	2.19 (1.10)
က	800		799.0 (400.7)	2.77 (1.39)	400		399.5 (200.4)	1.96 (0.98)	099		659.2 (330.2)	2.52 (1.26)
4	1000		998.7 (500.9)	3.10 (1.55)	230		529.3 (265.5)	2.26 (1.13)	820	····	819.0 (410.7)	2.81 (1.40)
9	1200		1198.5 (601.1)	3.40	099		659.2 (330.2)	2.52 (1.26)	940		938.8 (470.8)	3.01 (1.50)
7	1400	- 11 - 1 - 1 - 1	1398.2 (701.2)	3.67 (1.84)	750		749.1 (375.7)	2.69	1050		1048.7 (525.9)	3.18 (1.59)
æ	1500		1498.1 (751.3)	3.80	820		848.9 (425.8)	2.86 (1.43)	1200		1198.5 (601.1)	3.40 (1.70)
01	1500		1498.1 (751.3)	3.80	950	-	948.8 (475.8)	3.02	1200	-	1198.5 (601.1)	3.40 (1.70)

With side tanks. Should be equal to rule value of 116.9. Scantlings for alternate frame spacing.

NOTE: Yield stress assumed to be 50,000 psi.

TABLE B-1.2 (Continued)
DET NORSKE VERITAS STRENGTHENING
FOR NAVIGATION IN ICE

		Plating Thick. (in)	09.0				0.85	1.1		
	<u></u>	Frame S.M. (in³)	116.9				1161	1451		
	AFT	Frame Spacing (in)	32.9				20.5	20.5		
		$\frac{P}{(psi)}$	N/A				N/A	N/A	 	
		Plating Thick. (in)	0.67				0.68	0.98	•	
의	HIP HIP	Frame S.M. (in³)	116.9				1911	1451		
M.V. ARCTIC	MIDSHIP	Frame Spacing (in)	32.9				20.5	20.5		
2 1		P (psi)	N/A				N/A	N/A		
		Plating Thick. (in)	1.00	IAA	18	21	0.85	1.11		
	ARD	Frame S.M. (in³)	12.0 325-242	Same as ABS		Same as ABS I	191	1451		
	FORMARD	Frame Spacing (in)	12.0	Same	Same	Same	20.5 1161	20.5		
		P (psi)	N/A				N/A	N/A		
•		Ice Class	ICEC*	IA*	81	C	Icebreaker	Arctic Icebreaker		

* Scantlings should not exceed ABS IC.

TABLE B-1.2 (Continued)

- Contract Contracting - Contr

BUREAU VERITAS STRENGTHENING FOR NAVIGATION IN ICE

	Plating Thick. (in)	1.10	0.80	0.77	09.0						
AFT	Frame S.M. (in³)	233.8- 116.9	233.8- 116.9	116.9	116.9						
AF	Frame Spacing (in)	16.5	16.5	32.9	32.9						
	$\frac{P}{(psi)}$	A A	× ×	X X	N/A	,				 	
	Plating Thick. (in)	1.20	0.80	0.77	0.67						
4IP	Frame S.M. (in³)	116.9	116.9	116.9	116.9						
MIDSHIP	Frame Spacing (in)	16.5	16.5	32.9	32.9						
	(psi)	N/A	N/A	N/A	N/A						
	Plating Thick. (in)	1.26	1.01	1.01	0.84	IAA	IA	18	IC		
80	Frame S.M. (in³)	233.8- 1.16.9	233.8- 116.9	233.8- 116.9	116.9 87.7	as ABS	as ABS IA	Same as ABS IB	Same as ABS		
FORWARD	Frame Spacing (in)	16.5	16.5	16.5	16.5	Same	Same	Same	Same		
	$\frac{P}{(psi)}$	N/A	N/A	N/A	N/A						
	Ice	Glace I-Super	_		111	۲					
		Glace]	Glace]	Glace II	Glace III	IA Super	IA	18	21		

*Rule values are from ABS.

TABLE B-1.2 (Continued)

NIPPON KAIJI KYOKAI STRENGTHENING FOR NAVIGATION IN ICE M.V. ARCTIC

_				_			:	, -	_			
		FORWARD	RO			MIDSHIP	HIP			AFT		
Ice	$\frac{P}{(psi)}$	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	(psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	(psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)
¥	N/A	16.5	10.91	1.57-	N/A	16.5	134.6	1.04	N/A	16.5	10.91	1.12-
⋖	N/A	16.5	7.27	1.31-	N/A	16.5	90.2	0.94	N/A	16.5	7.27	1.12- 0.94
ω	N/A	16.5	4.96	1.31-	N/A	32.9	116.9	0.89	A/A	16.5	4.96	0.80-
ပ	N/A	16.5	2.31	1.12-0.94	N/A	32.9	116.9	0.67	N/A	16.5	2.31	0.60
IA-Super		Same	as ABS	IA	·							
IA		Same	as ABS	IA								
18		Same	as ABS	18								
10		Same	Same as ABS	21								

V = 17 knots

TABLE B-1.2 (Continued)

USSR REGISTER OF SHIPPING STRENGT INING FOR NAVIGATION IN ICE

	Plating Thick. (in)	†	0.84	0.83	0.77	09.0	09.0	
	Frame S.M. (in³)		120.6	79.5	116.9	116.9	116.9	
AFT	Frame Spacing (in)		16.5	16.5	32.9	32.9	32.9	
	$\frac{P}{(psi)}$	\ \frac{\frac{1}{2}}{2}	255	224	N N	¥.	A	
	Plating Thick. (in)	Each Vessel Considered Separately	0.84	0.83	0.77	0.67	0.67	
HIP	Frame S.M. (in³)	nsidered	120.6	79.5	116.9	116.9	116.9	
MIDSHIP	Frame Spacing (in)	Vessel Co	16.5	16.5	32.9	32.9	32.9	
	$\frac{P}{(psi)}$	– Each	255	224	N A	N	AN A	
	Plating Thick. (in)		1.06	1.00	1.00	0.84	0.84	
RD	Frame S.M. (in³)		98.6	45.1	140.3- 116.9	116.9-	116.9	
FORWARD	Frame Spacing (in)		16.5	16.5	16.5	16.5	19.7	
	P (psi)		409	245	A	Ä	Ä	,
	Ice	A / A	V,	LV	72	V3	V4	

NOTE: Rule scantlings are from ABS.

TABLE B-1.2 (Continued)

REGISTER OF THE PEOPLES REPUBLIC
OF CHINA
M.V. ARCTIC*

				•	E	M.V. AKCIIC*	k , 1	•				
		FORWARD	IARD			MIDSHIP	HIP			AFT	<u>_</u>	
Ice Class	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Frame Spacing S.M. (in) (in ³	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Frame Plating S.M. Thick. (in³) (in)
*18	Ą	M .	234	1.21	A	16.5	116.9	0.94	NA	16.5	234	0.84
- BI	₹	16.5	234	1.00	N A	16.5	116.9	0.80	NA	16.5	234	0.80
811	≨		323	0.94	¥	32.9	116.9	0.74	NA A	32.9	116.9	0.74
BIII	¥		116.9	0.84	¥	32.9	116.9	0.67	¥	32.9	116.9	09.0
æ	¥	16.5	116.9-	0.76	¥	32.9	116.9	0.67	ЙĀ	32.9	116.9	09.0
(River			35.1									
, 613657												
				_								

*Rule scantlings are from ABS.

TABLE B-1.3

ABS STRENGTHENING FOR NAVIGATION IN ICE ARCTIC TANKER

ARCITO MINER	FORWARD	Frame Plating Frame Frame Plating S.M. Thick. P Spacing S.M. Thick. P Spacing S.M. Thick. (in) (in) (in) (in) (in) (in) (in)	38.4 1.00 NA 19.8 38.4 1.00* NA 19.8 38.4 1.00	38.4 1.00 NA 39.5 38.4 1.00* NA 39.5 38.4 1.00	38.4 w/ 1.00 NA 39.5 38.4 1.00* NA 39.5 38.4 0.78 28.8 inter	67.8 1.81 122.5 39.5 35.4** 1.33 89.5 39.5 25.9** 1.15	61.7 1.73 98.0 39.5 28.3** 1.20 65.5 39.5 18.9** 0.99	55.5 1.64 65.5 39.5 18.9** 0.99* 41.0 39.5 11.9** 0.80	49.4 1.55 34.1 39.5 9.85** 0.74 17.1 39.5 4.9** 0.55***
-	ARD	<pre>Plating Thick. (in)</pre>	4 1.00	4 1.00	w/ 1.00 ter	3 1.81	7 1.73	5 1.64	4 1.55
	FORW	Frame P Spacing (psi) (in)	NA 19.8	NA 19.8	NA 19.8 28	234.5 39.5	213.5 39.5	192.0 39.5	171.0 39.5
-	.	Ice	⋖	æ	ပ	IAA	IA	18	C

Y = 50,000 psi

^{***}Should probably be equal to rule value of 0.78.
**Should probably be equal to rule value of 38.4.
*Should probably be equal to rule value of 1.05.

TABLE B-1.3 (Continued)

LLOYD'S STRENGTHENING FOR NAVIGATION IN ICE

		Plating Thick. (in)	1.15	1.00	1.00	0.78	1 1	1	
	.	Frame S.M. (in³)	38.4	38.4	38.4	38.4			
	AFT	Frame Spacing (in)	19.8	19.8	39.5	39.5			
		(psi)	A	AN	NA	AX.			
		Plating Thick. (in)	1.25	1.00*	1.00*	1.05			
(F)	HIP	Frame S.M. (in³)	38.4	38.4	38.4	38.4		ABS IB	ABS
ARCTIC TANKER	MIDSHIP	Frame Spacing (in)	19.8	19.8	39.5	39.5	Same as	Same as	Same as
ARC		P (psi)	NA A	AN	Ā	X			
_		Plating Thick. (in)	1.25	1.00	00.1	w/ 1.00 30.7 er			
	FORWARD	Frame S.M. (in³)	38.4	38.4	38.4	38.4 w/ 9.2-30.7 inter			
	FOR	Frame Spacing (in)	19.8	19.8	19.8	19.8			
		P (psi)	NA	NA NA	¥	Š Š			
_		Ice Class	*	_	2	က	IA Super	IA I	21

* Should probably be equal to rule value of 1.05.

TABLE B-1.3 (Continued)

CANADIAN ASPPR STRENGTHENING FOR NAVIGATION IN ICE ARCTIC TANKER

		FORWARD	IARD			MIDSHIP	HIP			AFT	þ -	
Ice	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	(psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)
,-	400	39.5 (19.8)³	106.2 (53.3)3 (2.36	100	39.5 (19.8)	26.6 ² (13.3)	1.18 (0.59)	100	39.5 (19.8)	26.6** 1.18 (13.3) (0.59	* 1.18 (0.59)
1A	009		159.4 (79.9)	2.88 (1.45)	260		69.1 (34.6)	1.90 (0.95)	325	-	86.3 (43.3)	2.12 (1.06)
2	800		212.5 (106.5)	3.33 (1.67)	400		10 6. 2 (53.3)	2.36 (1.18)	200		132.8 (66.6)	2.63 (1.32)
က	1000	<u>.</u>	265.6 (133.1)	3.72 (1.87)	230		140.8 (70.6)	2.71 (1.36)	099		175.3 (87.9)	3.03 (1.52)
4	1200	_,,	318.7 (159.8)	4.08 (2.04)	099		175.3 (87.9)	3.03	820		217.8 (109.2)	3.37 (1.69)
9	1400		371.8 (186.4)	4.41 (2.21)	750		199.2 (99.8)	3.23 (1.62)	940	·	249.7 (125.1)	3.61 (1.81)
7	1500		398.4 (199.7)	4.56 (2.92)	820		225.7 (113.2)	3.43 (1.72)	1050		278.9 (139.8)	3.82 (1.91)
8	1500		398.4 (199.7)	4.56 (2.29)	950		252.3 (126.5)	3.63 (1.82)	1200		318.7 (159.8)	4.08 (2.04)
00	1500		398.4 (199.7)	4.56 (2.29)	950		252.3 (126.5)	3.63 (1.82)	1200		318.7 (159.8)	4.08 (2.04)

No side tanks; waste stowed next to shell. Should be equal to rule value of 38.5. Scantlings for alternate frame spacing.

TABLE B-1.3 (Continued)
DET NORSKE VERITAS STRENGTHENING FOR
NAVIGATION IN ICE

~	-			<u>-</u>	« I	ARCTIC TANKER	KER		_			
		FORWARD	RO			MIDSHIP	HIP			AFT		
Ice	P (psi)	Frame Spacing (in)	Frame S.M. (in)	Plating Thick. (in)	P (ps1)	Frame Spacing (in)	Frame S.M. (in)	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame S.M. (in)	Plating Thick. (in)
ICE C* N/A	N/A	12.0	131- 760	1.00	N/A	39.5	38.4	1.05	N/A	39.5	30.4	0.78
IA*		Same	Same as ABS	IAA								
ΙΑ		Same	Same as ABS	IA								
18		Same	Same as ABS	18								
)I		Same	Same as ABS	21								
Icebreaker	N/A	27.4	61.2	3.17	N/A	27.4	61.2	2.53	N/A	27.9	61.2	3.17
Arctic Icebreaker	N/A	27.4	76.5	4.12	N/A	27.9	76.5	3.29	N/A	27.9	76.5	4.12
									_			

* Scantlings should not exceed ABS IC.

TABLE B-1.3 (Continued)
BUREAU VERITAS STRENGTHENING
FOR HAVIGATION IN ICE

TOTAL STREET, STREET,

-	_			_	AR	ARCTIC TANKER*	ER*		_			
		FORWARD	2			MIDSHIP	HIP			AFT		
Ice	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	$\frac{P}{(psi)}$	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)
Glace I-Super	N/A	19.8	76.8- 38.4	1.26	N/A	19.8	38.4	1.26	N/A	19.8	7.68- 38.4	1.26
Glace I	N/A	19.8	76.8- 38.4	1.00	N/A	19.8	38.4	1.00**	N/A	19.8	7.68-38.4	1.00
Glace II	N/A	19.8	76.8- 38.4	1.00	N/A	39.5	38.4	1.00**	N/A	39.5	38.4	1.00
III	8 ∀ A	19.8	38.4- 28.8	1.00	N/A	39.5	38.4	1.00**	N/A	39.5	38.4	1.00
IA Super		Same	as ABS IAA	IAA								
IA		Same	as ABS	IA								
18		Same	as ABS IB	18								
IC	••••••	Same as	as ABS IC	21								
-												

** Should be equal to rule value of 1.05. * Rule values are from ABS.

TABLE B-1.3 (Continued)

CONTRACTOR OF THE PROPERTY OF

NIPPON KAIJI KYOKAI STRENGTHENING FOR NAVIGATION IN ICE

•	-			-	A	ARCTIC TANKER	띪	-				
		FORWARD	RD.			MIDSHIP	HIP			AFT	-	
Ice	P (psi)	Fr Spa (1	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Spacing (in)	Frame S.M. (in³)	Plating Thick. (in)	P (psi)	Frame Spacin (in)	Frame S.M. (in³)	Plating Thick. (in)
*	N/A	19.8	185.7	1.99-	N/A	19.8	98.7	1.31	N/A	19.8	185.7	1.41-
<	¥	19.8	123.8	1.66-	A A	19.8	66.2	1.18	N/A	19.8	123.8	1.41-
₩	M/A	19.8	84.4	1.66-	N/A	39.5	38.4	1.12	N/A	19.8	84.4	1.00-
ပ	4	19.8	39.4	1.41	N/A	39.5	38.4	1.05	N/A	19.8	39.4	0.78
IA-super		Same	Same as ABS IAA	<u>*</u>								
ΥI		Series	as ABS IA									
18		Same	as ABS	18								
10		Same	as ABS	10								

V = 24 knots

TABLE B-1.3 (Continued)
USSR REGISTER OF SHIPPING
STRENGTHENING FOR NAVIGATION IN ICE

Secondary Associated Exhaustery European Branches

Each Vessel Considered Separately 487	essel Considered Separately 19.8 51.8 1.39 487 19.8 51.8 19.8 34.2 1.35 458 19.8 34.2 39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 1.05 NA 39.5 38.4
487 19.8 458 19.8 NA 39.5 NA 39.5	487 19.8 458 19.8 NA 39.5 NA 39.5
19.8 34.2 1.35 458 19.8 34.2 39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 1.05 NA 39.5 38.4	19.8 34.2 1.35 458 19.8 34.2 39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 1.05 NA 39.5 38.4
39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 1.05 NA 39.5 38.4	39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4
39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 1.05 NA 39.5 38.4	39.5 38.4 1.05 NA 39.5 38.4 39.5 38.4 NA 39.5 38.4
39.5 38.4 1.05 NA 39.5 38.4	39.5 38.4 1.05 NA 39.5 38.4

NUTE: Rule scantlings are from ABS.

TABLE B-1.3 (Continued)
REGISTER OF THE PEOPLES REPUBLIC
OF CHINA

ARCTIC TANKER* MIDSHIP Frame Frame Plating P Spacing S.M. Thick. (psi) (in) (in³) (in) (in) NA 19.8 38.4 1.26 N NA 39.5 38.4 1.00*** N NA 39.5 38.4 1.05 N NA 39.5 38.4 1.05 N	FORWARD P Spacing S.M. Thick. (psi) (in) (in³) (in) NA 19.8 76.8 1.00 NA 19.8 76.8 1.00 NA 19.8 38.4 1.00 NA 19.8 38.4-11.5 0.55**	Ice Class (psi) BI* NA BII NA BIII NA BIII NA BIII NA	ARCTIC TANKER*		Frame Frame Plating Frame Frame Spacing S.M. Thick. P Spacing S.M. (in) (in) (in) (in)	19.8 76.8 1.26 NA 19.8 38.4	19.8 76.8 1.00 NA 19.8 38.4	19.8 76.8 1.00 NA 39.5 38.4 1	19.8 38.4 1.00 NA 39.5 38.4 1	19.8 38.4-11.5 0.55** NA 39.5 38.4	
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** Should be equal to rule value of 1.05. ** Should be equal to rule value of 0.78. * Rule Scantlings are from ABS.

APPENDIX B-2 CALCULATED LOAD-CARRYING CAPABILITIES OF RESULTING SCANTLINGS FOR THREE REPRESENTATIVE SHIPS

METHOD USED TO CALCULATE THE LOAD CARRYING CAPABILITY OF SHELL PLATING AND TRANSVERSE FRAMES

The load carrying capability of each of the ice strengthened structures was calculated by the method used by Johansson [B-16] in the analysis of ice damage data. This method assumes that the plating and framing can no longer carry a load when 3 plastic hinges are formed.

Plating is assumed to be a fixed-fixed beam with a uniformly distributed load. Then the pressure to form 3 plastic hinges is

$$P \left[psi \right] = \frac{4\sigma_y t^2}{s^2 f_d} \tag{B-1}$$

where

 σ_y = yield stress of the material [psi]

t = plating thickness [in]

8 = frame spacing [in]

 f_d = a factor which gives a reduction in plating stress due to limited vertical extension of the ice pressure

Transverse frames are assumed to be fixed-fixed beams with a uniformly distributed load 800 mm long acting at mid-span. Then the pressure which the frames will support prior to development of three plastic hinges is:

$$P = \frac{16\sigma_y \quad [SM]}{cs \quad (2l-c)} \tag{8-2}$$

where

 $\sigma_{\!_{\mathcal{U}}}$ and s are defined above

 \tilde{l} = frame span [ft]

c = extent of the load [in]

SM = section modulus of the frame and associated plating [in³]

Substituting 800 mm [31.5 in] for σ and applying unit conversion constants, equation (B-2) becomes:

$$P [psi] = \frac{0.254 \, ^{\circ} y \, [S.M.]}{s \, (12l-15.75)}$$
 (B-3)

Then the normal load carrying capability is the load the plating or framing will carry (P) over the pressure specified in the rules $(P_{\rm rule})$.

TABLE 8-2.1
COMPARISON OF ICE STRENGTHENED SCANTLINGS
IN TERMS OF NORMALIZED LOAD CARRYING CAPABILITY

PNI	AD	STAR

			FRAME SPAC.	FRAME S.M.	PLATE THICK.	P/P _{Ru1e}	Pplate	Frame	P/P _{Rule}
ABS	CLASS +A1	AREA	[in] 25.8	[in³] 5.8	[1n] 0.40	NA	55	33	MA.
	A	Bow & Stern B	25.8 12.9	5.8 5.8	0.42 0.60	NA 7.35	60 441	33 66	MA 2.00
	•	Ň S	12.9 12.9	5.8 5.8	0.50 0.50	5.58 5.12	307 307	66 66	2.00
	В	8	12.9	5.8	0.60 0.53	7.35	441	66 33	2.00 1.00
		S	25.8 25.8	5.8 5.8	0.46	1.75 1.20	96 72	33	1.00
	С	8 M	12.9 25.8	5. } 5.8	0.50 0.40	5.12 1.00	307 55	58 33	1.76 1.00
	IAA	S B	25.8 25.8	5.8 51.4	0, 42 1, 26	1.00 9.03	60 542	33 293	1.00 8.86
	1700	M S	25.8 25.8	26.9 19.6	0.96 0.83	5.73 3.92	315 235	153 112	4.64 3.39
	IA	8	25.8	46.8	1.24	8.75	525	267	8.09
		M S	25.8 25.8	21.5 14.4	0. 86 0.72	4.60 2.95	253 177	123 82	3.73 2. 48
	18	B M	25.8 25.8	42.1 14.4	1.18 0.72	7. 9 2 3.22	475 177	240 82	7.27 2. 48
	IC	S B	25.8 25.8	9.0 37.5	0.59 1.11	1. 98 7.02	119 421	51 214	1.55 6.48
	10	M S	25.8 25.8	7.5 5.8	0.54 0.42	1.82	100	43 33	1.30
FFOAD.2	1•	В	12.9	5.8	1.25	31.93	1916	55	2.00
		Ñ S	12.9 12.9	5.8 5.8	0.55 0.55	6.75 6.18	371 371	66 66	2.00 2.00
	1	8 M	12.9 12.9	5.8	0.52	5.53		66	2.00
		S	12.9	5.8 5.8	0. 50 0. 50	5.58 5.12	307 307	66 66	2.00 2.00
	2	B M	12.9 25.8	5.8 5.8	0. 52 0. 5 6	5. 53 1. 9 5	332 167	66 33	2.00 1.00
	3	S B	25.8 12.9	5.8 4.8	0.56 0.50	1.78 5.12	107 307	33 55	1.00 1.67
	-	M S	25.8 25.8	5.8 5.8	0.40 0.42	1.00 1.00	55 60	33 33	1.00 1.00
	IA Supe IA	,		•••	5	,,,,,	•	•	
	ie IC	}	- Same as ABS-						
ASPPR	1) B	25.8	54.8	1.22	8.47	508	313	9.48
	•	M S	j	21.9 21.9	0.77 0.77	3.67 3.37	202 202	125 125	3.79 3.79
	18	8	l	87.7	1.54	13.50	810	501	15.18
		M S		57.0 71.2	1.24	9.55 11.00	525 660	325 406	9.85 12. 30
	2	8 M		131.5 8 7.7	1. 88 1.54	20.12 14.70	1207 809	750 501	22.73 15.18
	3	S B	}	109.6 175.4	1.72 2.18	16. 83 27.05	1010 1623	626 1001	18. 97 30. 33
	•	M S	Ì	116.2 144.7	1.77 1.98	19.45 22.31	1070 1339	663 826	20.00 25.03
	4	8		219.2	2.43	33.60	2016	1251	37.91
		M S		144.7 179.7	1.98 2.20	24.34 27.53	1652	1026	25.03 31. 09
	•	B. M	Į	263.0 164.4	2.66 2.11	40.27 27.63	2416 1520	1501 938	45.46 20.42
	,	Š	•	206.0 306.9	2.36 2.88	31.70 47.1P	1902 2831	11 76 1752	35.64 53.09
	•	M S	1	186.3 230.2	2.24 2.49	31.14 35.28	1713 2117	1063 1314	32.21 39.82
	8	B		328.8	2.98 2.37	50.53	3032	1877	56.88 36.00
		M S		208.2 263.0	2.66	34.87 40.27	1918 2416	1188 1501	45.46
	10	8 M		328.8 208.2	2.9 0 2.37	50.53 34.87	3032 1918	1877 1186	56.86 36.00
		ŝ	ł	263.0	2.66	40.27	2416	1501	45.48

TABLE 8-2-1 (Continued) COMPARISON OF ICE STRENGTHENED SCANTLINGS IN TERMS OF NORMALIZED LOAD CARRYING CAPABILITY

POLAR STAR

			2	9-06-31A6					
NULE	CLASS	AREA	FRAME SPAC. [in]	FRAME S.M.	PLATE THICK. [1n]	P/P _{Rule}	Plate	France	P/P _{Rule}
DMA	ICE C	8 19	12.0 25.8	7.4 5.8	0.69	11.02	661	91	2.77
		Š	25. 6	5.#	0. 4 0 0. 4 2	1.00 1.00	55 60	73 33	1. 86 1. 86
	ICEBREAKER	B	16.3 16.3	27.5 27.5	1.38	9.77	586	246	7.52
		S	16.3	27.5	1.11 1.38	6.89 9.77	379 586	248 248	7. 52 7. 52
	ARCTIC ICEBREAKER	8	16.3 16.3	34.4 34.4	1.79 1.44	16.42 11.60	985 638	311 311	9.42
		Š	16.3	34.4	1.79	16.42	965	311	9.42
	IA*								
	18	-	Same as ABS -						
DUREAU	Glace 1-Super		12.9	8.7	1,26	32.43	1946	99	3.00
VERITAS		# S	12. 9 12. 9	5. 8 8.7	1.26 1.26	35.38 32.43	1946 1946	66 99	2.00 3.00
	Glace 1		12.9	8.7	0.60	7.35	441	99	3.00
		M S	12.9 12.9	5. 6 0.7	0.48 0.48	5.15 4.72	263 263	# 79	2.00 3.00
	Glace 2		12.9	8.7	0.60	7.35	441	99	3.60
		N S	25. 8 25. 8	5. 6 5. 6	0.4 6 0.46	1.31 1.20	72 72	33 33	1. 00 1.00
	Glace 3		12.9	5.1	0.50	5.12	307	58	1.76
		M S	25. 8 25. 8	5.8 5.8	0.40 0.42	1.00 1.00	55 6 0	33 33	1.00 1.00
	IA Super								
	19 {	-	Same as ABS						
NUSSIAN	IC)	8	12.9	15.6					
	***	Ħ	12.9	10.1	0.71 0.54	10.30 6.51	618 358	1 78 115	5.39 3.46
	Al	S	12.9 12.9	10.1 7.2	0.54 0.60	5.97 7.35	358 441	115 82 -	3.48
		Ä	12.9	6.3	0.50	5.58	307	72	2.4 6 2.18
	A2	8	12.9 12.9	6.3 6.4	0.50 0.60	5.12 7.35	307 441	72 73	2.18 2.21
		M S	25.8 25.8	5.8 6.4	0.46	1.31	72	33	1.00
	A3		12.9 25.8	5.1	0.46 0.50	1. 20 5.12	72 307	37 58	1.12 1.76
		M S	25.8 25.8	5.8 5.8	0.40 0.42	1.00	55 60	33 33	1.00
	M		15.5	5.8	0.50	3.58	215	35 \$5	1. 00 1.67
		M S	25.8 25.8	5.8 5.8	0.40 0.42	1.00 1.00	55 60	33	1.00
	AA		36.0	57.1	1.20	19.33	1160	525	15.91
-		N.	16.0	27.5	0.88	11.35	624	253	7.67
	A	S B	16.0 16.0	57.1 ` 38.1	0.87 1.01	10.17 13.70	610 822	525 351	15.91 10. 64
		M S	16.0 16.0	18.7 38.1	0.79	9.15	503 610	172 351	5.21 10.64
			16.0	26.0	0.87 1.01	10.17 13.70	822	239	7.24
	_	M S	25.8 16.0	5.8 26.0	0.69 0.63	2.96 5.33	163 320	33 239	1.00 7.24
	C		16.0		0.87	10.17	610	111	
		M S	25.8 16.0	12.1 5.8 12.1	0.67 0.42	2.7 8 2.77	153 142	33 111	3.36 1.90 3.36
	[A Super]	_		****		••••	•••	***	0.00
	1A 19		Same as ABS -						
	ic)	1							
PEOPLES REPUB LIC OF CHIMA		H S	12. 9 12. 9	11.6 5.8	0.72 0. 56	10.60 7.00	636 385	132 66	4.00 2.90
			12.9	11.6	0.50	5.12	307	132	4.00
	18	B M S	12.9 12.9	11.6 5.6	0.60 0.50	7.35 5.58 4.72	441 307	132 66 132	4.00 2.00
	BII	\$ B	12.9 12.9	11.6 11.6	0.48	4.72 6.42	283 385	132 132	4.00 4.00
	411	M S	25.8	5.8	0.56 0.46	1.31	72	33	1.00
	BILL		25. 6 12.9	5.6 5.0	0.44 0.50	1,10 5,12	56 307	33 66	1.00
	4.11	B M S	25.3	5.8	0.40	1.00	55	33	1.00
		8	25.8 12.9	5.6 3.8	0.42 0.55	1.00 6.18	60 371	33 43	1.00 1.30
	(River	Ä	25.8	5.8	0.40	1.00	55 60	33 33	1.00
	Vessels)	\$	25.8	5.8	0.42	1.00	-	33	1.00

TABLE 8-2.2 COMPARISON OF ICE STRENGTHENED SCANTLINGS IN TERMS OF NORMALIZED LOAD CARRYING CAPABILITY

M.V. ARCTIC

RULE	CLASS	AREA	FRAME SPAC.	FRAME S.M. [in ³]	PLATE THICK.	<i>P/P</i> Ru1e	P _{Plate} [ps1]	P _{Frame}	P/P _{Rule}
ABS	+A1	M B&S	32.9 32.9	116.9 116.9	0.67 0.60	NA NA	104 83	146 146	NA NA
	A	B	16.5 16.5	116.9 116.9	1.00 0.84	9.12 5.13	757	292	2.00
	В	S B	16.5 16.5	116.9 116.9	0.84	6.43	534 534	292 292	2.00
	•	H S	32.9 32.9	116.9 116.9 116.9	1.00 0.89 0.77	9.12 1.76 1.65	757 183 137	292 146	2.00 1.00
	C	8	16.5 32.9	102.3 116.9	0.84 0.67	6.43	534	146 255	1.00
	IM	S B	32.9 32.9	116.9	0.67	1.00 1.25	104 194	146 146	1.00
	•	M S	32.9 32.9 32.9	122.3 116.9	1.57 1.16 1.00	6.85 2.99 2.78	569 311 231	293 153 146	2.01 1.05
	1A	8 M	32.9 32.9	213.2 116.9	1.50 1.04	6.27 2.40	520	267	1.83
	18	S B	32.9 32.9	116.9	0.87 1.43	2.11	250 175	146 146	1.00
	•••	M S	32.9 32.9	116.9 116.9	0.87 0.70	5.69 1.68 1.36	472 175 113	240 146 146	1.64 1.00
	IC	B M	32.9 32.9	170.8 116.9	1.35 0.67	5.07 1.00	421 104	214	1.00
LLOYD'S	1•	S	32.9 16.5	116.9 116.9	0.60	1.00	83	146 146	1.00
	·	M S	16.5 16.5	116.9 116.9	1.25 0.75 0.67	14.25 4.10 4.10	1183 426 340	292 292 292	2.00 2.00 2.00
	7	8 14	16.5 16.5	116.9 116.9	0.80 0.67	5.84 3.27	485 340	292	2.00
	2	5 B	16.5 16.5	116.9 116.9	0.67 0.80	4.09 5.84	340	292 292	2.00 2.00
		M S	32.9 32.9	116.9 116.9	0.67 0.87	1.00	485 104 175	292 146 146	2.00 1.00 1.00
	3	B M	16.5 32.9	96.5 116.9	0.67 0.67	4.09 1.00	340 104	240 146	1.64 1.00
	IA Super)	S	32.9	116.9	0.60	1.00	83	146	1.00
	IA IB IC		Same as ABS						
ASPPR	1 ,	8	32.9	249.7 116.9	1.55 0.98	6.69 2.13	555	313	2.14
	1A	S B		116.9 399.5	0.98 1.96	2.67 10.68	222 222 887	146 146	1.00
		M S		116.9 324.6	0.98 1.77	2.13 8.72	222 724	500 146 406	3.42 1.00 2.78
	2	8 M	•	599.2 259.7	2.40 1.58	10. 02 5. 54	1330 576	750 325	5.14 2.23
	3	S B		499.4 799.0	2.19 2.77	13.34	1108 1772	625 1000	4.28 6.85
		M S		399.5 659.2	1.96 2.52	8.53 17.46	887 1467	500 826	3.42 5.66
	4	B	ļ	998.7 529.3	3.10 2.26	26.73 11.35	2219 1180	1251 663	8.57 4.54
	6	S B	ļ	819.0 11 98 .5	2.81 3.40	21.98 32.17	1824 2670	1026 1501	7.03 10.28
	_	M S		659.2 938.8	2.52 3.01	14.11 25.22	1467 2093	826 1176	5.66 8.05
	7	8 M S		1398.2 749.1	3.67 2.69	37.48 16.07	3111 1671	1751 938	11.99 6.42
	8	8 M		1048.7 1498.1	3.18 3.80	28.14 40.18	2336 3335	1313 1876	8.99 12.85
	10	S		848.9 1198.5	2.86 3.40	18.16 32.17	1889 2670	1063 1501	7.28 10.28
	10	B M S	ļ	1498.1 948.8 1198.5	3.80 3.02 3.40	40.15 20.26 32.17	3335 2107 2670	1876 1188 1501	12.85 8.14
DMA	ICE C	8 M	12.0 32.9	284.0 116.9	1.00	••	1402	975	10.28 6.67
	ICEBREAKER	Š	32.9	116.9	0.67 0.60	1.00	104 83	146 146	1.00
	SCHOOLINER	H S	20.5 20.5 20.5	1161.0 1161.0 1161.0	0.85 0.68 0.85	4.46 2.28 4.46	370 237 370	2333 2333 2333	15.98 15.98 15.98
	ARCTIC TCEBREAKER	B	20.5 20.5	1451.0 1451.0	1.11 0.98	7.60 4.72	631 491	2916	19.97
	IA+ }	Ŝ	20.5	1451.0	1.11	7.60	631		19.97 19.97
	iA } .	•	Same as ABS		• • •				• • ••

TABLE B-2.2 (Continued) COMPARISON OF ICE STRENGTHENED SCANTLINGS IN TERMS OF NORMALIZED LOAD CARRYING CAPABILITY

M.V. ARCTIC

RULE	CLASS	AREA	FRAME SPAC.	FRAME S.M.	PLATE THICK. [in]	P/P _{Rule}	P _{Plate} [psi]	P _{Frame} [ps1]	P/P _{Rule}
BUREAU VERITAS	Glace 1 Super	B M S	16.5 16.5 16.5	175.4 116.9 175.4	1.26 1.20 1.10	14.48 10.49 11.04	1202 1091 916	438 292 438	3.00 2.00 3.00
	Glace I	B M S	16.5 16.5 16.5	175.4 116.9 175.4	1.01 0.80 0.80	9.31 4.66 5.84	773 485 485	438 292 438	3.00 2.00 3.00
	Glace II	B M S	16.5 32.9 32.9	175.4 116.9 116.9	1.01 0.77 0.77	9.31 1.32 1.65	773 137 137	438 146 146	3.00 1.00 1.00
	Glace III	8 M S	16.5 32.9 32.9	102.3 116.9 116.9	0.84 0.67 0.60	6.43 1.00 1.00	534 104 83	255 146 146	1.75 1.00 1.00
	IA Super IA IB IC	•	Same as ABS		· · - · - · · · ·				-
RUSSIAN	¥A ,	B M S	16.5 16.5 16.5	120.6 120.6 120.6	1.06 0.84 0.84	10.25 5.13 6.43	851 534 534	301 301 301	2.06 2.06 2.06
	Λl	B M S	16.5 16.5 16.5	128.6 116.9 116.9	1.00 0.83 0.83	9.12 5.02 6.29	757 522 522	321 292 292	2.20 2.00 2.00
	2	B M S	16.5 32.9 32.9	128.6 116.9 116.9	1.00 0.77 0.77	9.12 1.32 1.65	757 137 137	321 146 146	2.20 1.00 1.00
	.13	B M S	16.5 32.9 32.9	102.3 116.9 116.9	0.84 0.67 0.60	6.43 1.00 1.00	534 104 83	255 146 146	1.75 1.00 1.00
	Λ4	B M S	16.5 32.9 32.9	116.9 116.9 116.9	0.84 0.67 0.60	6.43 1.00 1.00	534 104 83	292 146 146	2.00 1.00 1.00
NKK	AA .	B M S	16.5 16.5 16.5	1091.0 134.6 1091.0	1.44 1.04 1.03	18.92 7.88 9.67	1570 819 803	2724 336 2724	18.66 2.30 18.66
	A 2	B M S	16.5 16.5 16.5	727.0 90.2 727.0 496.0	1.20 0.94 1.03	13.13 6.43 9.67	1090 669 803	1815 225 1815 1238	12.43 1.54 12.43
	B C	M S B	16.5 32.9 16.5	116.9 496.0	1.20 0.89 0.74	13.13 1.76 5.00	1090 183 415	146 1238	8.48 1.00 8.48
	IA Super)	M S	16.5 32.9 16.5	231.0 116.9 231.0	1.03 0.67 0.60	9.67 1.00 3.29	803 104 273	577 146 577	3.95 1.00 3.95
	IA SUPEY IA IB IC		Same as ABS -	······································					····
PEOPLES REPUB- LIC OF CHINA	81*	8 M S	16.5 16.5 16.5	234.0 116.9 234.0	1.21 0.94 0.84	13.36 6.43 6.43	1109 669 534	584 292 584	4.00 2.00 4.00
	Bi	B M S	16.5 16.5 16.5	234.0 116.9 234.0	1.00 0.80 0.80	9.12 4.66 5.84	757 485 485	584 292 584	4.00 2.00 4.00
	BII	B M S	16.5 32.9 32.9	234,0 116.9 116.9	0.94 0.74 0.74	8.06 1.21 8.06	669 126 126	584 146 146	4.00 1.00 1.00
	8111	B M S	16.5 32.9 32.9	116.9 116.9 116.9	0.84 0.67 0.60	6.43 1.00 1.00	534 104 87	292 146 146	2.00 1.00 1.00
	B (River Vessels)	B M S	16.5 32.9 32.9	76.0 116.9 116.9	0.76 0.67 0.60	5.26 1.00 1.00	437 104 83	190 146 146	1.30 1.00 1.00

TABLE B-2.3 COMPARISON OF ICE STRENGTHENED SCANTLINGS IN TERMS OF NORMALIZED LOAD CARRYING CAPABILITY

AKLI	ı	TANKER

RULE	CLASS	AREA	FRAME SPAC. [in]	FRAME S.M.	PLATE THICK.	P/P _{Rule}	Pplata [ps1]	P _{Frame} [psi]	P/P _{Rule}
,ABS	+A)	M BBS	39.5 39.5	38.4 38.4	1.05 0.78	NA NA	196 108	166 166	MA NA
	A	B M S	19.8 19.8 19.8	38.4 38.4 38.4	1.00 1.05 1.00	5.03 3.05 5.03	543 598 543	332 332	2.00 2.00 2.00
	В	B M S	19.8 39.5 39.5	38.4 38.4 38.4	1.00 1.05 1.00	5.03 1.00 1.05	543 196 178	332 166 166	2.00 1.00 1.00
	С	B M S	19.8 39.5	33.6 38.4 38.4	1.00 1.05 0.78	5.03 1.00 1.00	543 196 108	290 166 166	1.75 1.00 1.00
	1AA	8 M 5		67.8 38.4 38.4	1.81 1.33 1.15	5.40 1.61 2.18	583 315 235	294 166 166	1.77 1.00 1.00
	18	8 M S		61.7 38.4 38.4	1.73 1.20 0.99	4.94 1.31 1.61	533 256 174	267 166 166	1.61 1.00 1.00
	18	В М S		55,7 38,4 38,4	1.64 1.05 0.80	4,44 1,00 1,06	479 196 114	241 166 166	1.45 1.00 1.00
	IC	B M S		49,4 38,4 38,4	1.55 1.05 0.78	3.96 1.00 1.00	428 196 108	214 166 166	1.29 1.00 1.00
LLOAD,2	1*	B M S	19.8 19.8 19.8	38.4 38.4 38.4	1.25 1.25 1.15	7.85 4.33 6.65	848 848 718	332 332 332	2.00 2.00 2.00
	1	B M S	19.8 19.8 19.8	38,4 38,4 38,4	1.00 3.05 1.00	5.03 3.05 5.03	543 598 543	332 332 332	2.00 2.00 2.00
	2	8 M S	19.8 39.5 39.5	38.4 38.4 38.4	1.00 1.05 1.00	5.03 1.00 1.65	543 196 178	332 166 166	2.00 1.00 1.00
	3	B M S	19,8 39,5 39,5	31.7 38.4 38.4	1.00 1.05 0.78	5.03 1.00 1.00	543 196 108	274 166 166	1.65 1.00 1.00
	IA Super IA IB IC		Same as ABS -			and the second			
ASPPR	1	B H S	39.5 	106.2 38.4 38.4	2.36 1.18 1.18	9.19 1.29 2.30	992 248 248	460 166 166	2.77 1.00 1.00
	1A	B M S		159.4 69.1 86.3	2.88 1.90 2.12	13.67 3.28 7.41	1477 643 800	690 299 374	4.16 1.80 2.25
	2	8 M S		212.5 106.2 132.8	3.33 2.36 2.63	18.28 5.06 11.40	1974 992 1231	920 460 575	5.54 2.77 3.46
	3	B M S		265.6 140.8 175.3	3.72 2.71 3.03	22.81 6.67 15.14	2463 1308 1635	1150 610 759	6.93 3.67 4.57
	4	8 M 5		318,7 175,3 217,8	4.08 3.03 3.37	27.44 8.34 18.72	2964 1635 2022	1380 759 943	8,31 4,57 5,68
	6	B M S	\ \	371.8 199.2 249.7	4.41 3.23 3.61	32.06 9.47 21.48	3462 1857 2320	1610 863 1081	9.70 5.20 6.51
	7	8 M S		398.4 225. <i>7</i> 278.9	4.56 3.43 3.82	34.28 10.69 24.06	3702 2095 2598	1725 977 1208	10.39 5.89 7.28
	8	B # 5		398.4 252.3 318.7	4.56 3.63 4.08	34.28 11.97 27.44	3702 2346 2964	1725 1093 1380	10.39 6.58 8.31
	10	8 M S		398.4 252.3 318.7	4.56 3.63 4.08	34.28 11.97 27.44	3702 2346 2964	1725 1093 1380	10.39 6.58 8.31

TABLE B-2.3 (CONTINUED) COMPARISON OF ICE STRENGTHENED SCANTLINGS IN TERMS OF NORMALIZED LOAD CARRYING CAPABILITY

ARCTIC TANKER

RULE	CLASS	AREA	FRAME SPAC.	FRAME S.M.	PLATE THICK.	P/P _{Rule}	P _{Plate} [psi]	P _{Frame} [psi]	P/P _{Ru1e}
DNA	ICE C	B M S	12.0 39.5 39.5	103.5 38.4 38.4	1.00 1.05 0.78	12.86 1.00 1.00	1389 196 108	1475 166 166	8.89 1.00 1.00
	ICEBREAKER	8 M S	27.9	61.2 61.2 61.2	3.17 2.53 3.17	28.13 9.87 28.13	3038 1935 3038	375 375 375	2.26 2.26 2.26
	ARCTIC ICEBREAKER	8 M S		76.5 76.5 76.5	4.12 3.29 4.12	47.51 16.69 47.51	5131 3272 5131	469 469 469	2.83 2.83 2.83
	IA IB IC		Same as ABS -					****	- -
BUREAU VERITAS	Glace I-Super	B M S	19.8 19.8 19.8	57.6 38.4 57.6	1.26 1.26 1.26	7.98 4.40 7.96	862 862 862	498 332 498	3.00 2.00 3.00
BUREAU VERITAS	Glace I	8 M S	19.8 19.8 19.8	57.6 38.4 57.6	1.00 1.05 1.00	5.03 3.05 5.03	543 598 543	498 332 498	3.00 2.00 3.00
	Glace II	8 M S	19.8 39.5 39.5	57.6 38.4 38.4	1.00 1.05 1.00	5.03 1.00 1.65	543 196 178	498 166 166	3.00 1.00 1.00
	Glace III	B M S	19.8 39.5 39.5	33.6 38.4 38.4	1.00 1.05 1.00	5.03 1.00 1.65	543 196 178	290 166 166	1.75 1.00 1.00
89 44	IA Super	•	Same as ABS -						
USSR	٧٨ ′	B H S	19.8 19.8 19.8	70.5 51.8 51.8	2.02 1.39 1.39	20.50 5.35 9.71	2214 1049 1049	609 447 447	3.67 2.69 2.69
	Δl	B M S	19.8 19.8 19.8	42.3 38.4 38.4	1.58 1.35 1.35	12.55 5.05 9.16	1355 989 989	365 332 332	2.20 2.00 2.00
	۸2	8 M S	19.8 39.5 39.5	42.3 38.4 38.4	1.00 1.05 1.00	5 03 1.00 1.65	543 196 178	365 166 166	2.20 1.00 1.00
	A3	B M S	19.8 39.5 39.5	33.6 38.4 38.4	1.00 1.05 0.78	5.03 1.00 1.00	543 196 108	290 166 166	1.75 1.00 1.00
	۸4	B M S	.23.7 39.5 39.5	38.4 38.4 38.4	1.00 1.05 0.78	3.67 1.00 1.00	396 196 108	277 166 166	1.67 1.00 1.00
- NKK	AA	B M S	19.8	185.7 98.7 185.7	1.83 1.31 1.30	16.82 4.75 8.49	1617 931 917	1604 853 -1604	9.66 5.14 9.66
	A	B M S		123.8 66.2 123.8	1.52 1.18 1.30	11.61 3.87 8.49	1254 756 917	1069 570 1069	6.44 3.43 6.44
	В	B M S	1 39.5 19.8	84.4 38.4 84.4	1.52 1.12 0.92	11.61 1.14 4.25	1254 223 459	729 166 729	4.39 1.00 4.39
8-45	c	8 M S	19.8 39.5 19.8	39.4 38.4 39.4	1.30 1.05 0.78	8.49 1.00 3.06	917 1 96 330	340 166 340	2.05 1.00 2.05
	IA Super IA IB IC	······································	Same as ABS				-		
PEOPLES REPUBLIC OF CHIMA	BI*	B M S	19.8 19.8 19.8	76.8 38.4 76.8	1.26 1.26 1.26	7.98 4.40 7.98	862 862 862	663 332 663	3.99 2.00 3.99
	81	B M S	19.8 19.8 19.8	76.8 38.4 76.8	1.00 1.05 1.00	5.03 3.05 5.03	543 598 543	663 332 663	3.99 2.00 3.99
	BIT	8 M S	19.8 39.5 39.5	76.8 38.4 38.4	1.00 1.05 1.00	5.03 1.00 1.65	543 196 178	663 166 166	3.99 1.00 1.00
	8111	B M S	39.5 39.5 39.5	38.4 38.4 38.4	1.00 1.05 0.78	1.65 1.00 1.00	178 196 108	166 166 166	1.00 1.00 1.00
PEOPLES REPUB- LIC OF CHI	B (River W Yessels)	B M S	19.8 39.5 39.5	25.0 38.4 38.4	0.55 1.05 0.78	1.52 1.00 1.00	164 196 108	216 166 166	1.30 1.00 1.00

APPENDIX B-3 TABULAR LISTING OF LOW-TEMPERATURE STEELS AND THEIR PROPERTIES

TABLE 8-3.1 STEEL TYPES USED FOR SHIPS MAVIGATING IN ICE

MATERIAL	REGION OF APPLICATION:							
SPECIFICATION SOURCE:	ICE BELT, ICE PRAMES, SHELL, MEATHER DECKS	ICE STRINGERS & OTHER ICE MEMBERS	STRUCTURE ADJ. TO SHELL & MEATHER DECKS	SUPERSTRUCT., INTERIOR STRUCTURE	SPECIAL APPLICATIONS			
American Bureau of Shipping (1980)	ABS MS Grades A,B,D,R,DG,CS							
	ABS MTS Grades AR32, DR32, EH32, AH36, DR36, EH36	Ditto	Ditto	Ditto				
Lloyd's Register of Shipping (1979) - British Classification Rules for Ships	LR MS Grades A,B,D,E, LR MTS Grades AH275, DH275, EH275, AH32, DH32, EH32,	Ditto	Ditto	Ditto				
	AH348, DH345, EH348, AM36, DH36, EH36							
Det Norske Veritas (1977)- Norwegian Classification Rules for Ships	DNV MS Grades NVA, MVB, MVD, NVE			n				
·-· · · · · · · · · · · · · · · · · · ·	DNV NTS Grades NVA27S, NVD27S, NVE27S, NVA32, NVD32, NVE32, NVA36, NVD36, NVE36, NVA40S, NVI40S, NVE40S	Ditto	Ditto	Ditto				
Bureau Veritas (1977) - French Classification Rules for Ships	BV MS Grades A, B, D, E EV WTE Grades AH32, UH32, EH32, AH36, DH36, EH356	Ditto	Ditto	Oltto				
Nippon Kaiji Koykai (1979) - Japanese Classification Rules for Ships		Ditto	Ditto	Ditto				
Germanischer Lloyd (1980) German Classification Rules for Shipe	GL MS Grades A, B, D, E GL NTS Grades A32, D32, E32, A36, D36, E36	Ditto	Ditto	Ditto				
Specifications for USCG 480-Poot Polar Class Icebreaker	CG-A537N for plates and shapes	CG-A537M for fabricated chapse; CG-A537M, ASTM- A537 Class 1, ASTM - A537 Class 2 for rolled shapes	CG-A537N for plates, ASTN - A537 Class 1 6 ASTN-A537 Class 2 for rolled shapes	ABS Steel Grades	HY-00 for fligh dock and around large dock openings			
Specifications for USCG 140-Poot Harbor Tug	ASTM-A537 Class t or 2, and ABS Grade S	ASTM-A537 Class 1 or 2, and ABS Grade E	ABS Steel Grades B, C or CS	ABS steel Grades B, C or CS				
Specifications for Nuclear Icebreaking Tanker	CG-A537M (except for shell)	CG-A537M	ABS Steel Grades (including shell)	ABS Steel Graded				

TABLE 8-3.2

STEEL TYPES PROPOSED FOR SHIPS NAVIGATING IN ICE

MATERIAL	REGION OF APPLICATION:							
SPECIPICATION SOURCE:	ICE BELT, ICE FRAMES, SHELL, WEATHER DECKS	ICE STRINGERS & OTHER ICE MEMBERS	STRUCTURE ADJ. TO SHELL 6 WEATHER DECKS	SUPERSTRUCT., INTERIOR STRUCTURE	SPECIAL APPLICATIONS			
Additional materials proposed for ice- strengthened ships as	ASTM-A 710 Gr.A, Class 3	Ditto	Ditto					
recommended by steel manufacturers	ASTM-A 633 Gr. A 6 B	•	•					
	ASTM-A 633 Gr. C		•					
	ASTM-A 633	•	•					
	ASTH-A 633		•					
	ASTM-A 737 Gr. B		-					
	ASTM-A 678 Gr. A	•	•					
	ASTM-A 678 Gr. B	•	•					
	ASTM-A 678	•						
	ABS Gr. V-039	•	•					
	ABS Gr. V-051	•						

TABLE 8-3.3
PROPERTIES OF STREET USED FOR ICE-STREETWEED SHIPS

STREL TYPE & GRADE	ABS	Lloyd's Register	Horake Veritas
	M& Gr. A Open-hearth, basic-oxygen,	MB Gr. A Open-hearth, electric-	MB Gr. MVA
PROCESS OF MANUFACTURE	electric-furnace, vacuum-	furnace, or basic-oxygen	or electric-furnece
	arc remeit, or electro-	process	process
DECKIDATION	sing remeit process Any method, except rismed	Any method, except rimmed	Any method, except rimmed
DEGREE TOWN	steel*	steel*	steel*
HEAT TREATMENT	Not required	Not required	Not required
CHEMICAL COMPOSITION	Except for Gr. A shapes 6 bars, the carbon content	The sum of carbon content plus 1/6 of the manganese	Carbon plus 1/6 of the
(Ladle Analysis - %)	+ 1/6 of the manganese	content shall not exceed	exceed 0.40%.
,	content is not to exceed	0.40%.	
	0.40%. If this condition		
	is satisfied, manganese may be up to 1.65%.		ĺ
ĺ	and the tap to the set.		
Carbon (max.)	0.23	0.23	0.23**
Manganese	2.5 x cerbon **	2.5 x carbon **	2-5 x carbon
Phisphorus (mex.) Suiphur (mex.)	0.04	0.05	0.04
Silicon	1	0.50 max.	0.35 max.
Chromium			
Nickel			
Hulybdenum Copper			
Titanium			
Vanadium			
Aluminum			
Others			
Motes:	*Rimmed steel is accepted	*Rimmed steel is accepted	*For thickn. 12.5 484
	for plates up to 12.5 HM	for plates up to 12.5 MM	(1/2 IN) rimmed steel may
	(1/2 IH).	(1/2 IN).	he accepted.
	**Min. for 12.5 MM (1/2 IM).	**Min. for 12.5 NM (1/2 IM).	**For thickn. 12,5 MM (1/2 IN) a higher carbon
	, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	('/ 2 14/ 5	content may be accepted
		T	upon special approval.
TENSILE REQUIREMENTS			
Ultimate KG/MM2 (KSI)	41 - 50 (58 - 71)	41 - 50 (58 - 71)	41 - 50 (58 - 71)
	24 (34) incl. 25 MM (1 IM)	24 (34)	24 (34) incl. 25 MM (1 IM)
1	23 (32) above 25 MM (1 IN)		23 (32) above 25 MM (1 IM)
Elongation (min.) % in 5.65 % MM (IN) or as	21 in 200 MM (8 EN) or 24 in 50 MM (2 IN)	22	22
noted (Ameres of spe.)	1 10 30 444 (2 14)		
<u> </u>			
CHARPY V-HOTCH IMPACT	None required	None required	None required
Temperature *C			
Energy, KG-M (FT-LB)			
NOT TEMPERATURE *C			
DYNAMIC TRAP ENERGY	 		
IN KG-M (PT-LB) AT 24°C	l	l .	
FOR 16 MM (5/R (N)	l		
THICK SPECIMEN	1	ł	
		·····	
ABRASION RESISTANCE AS	110 - 140	110 - 140	110 - 140
ABRASION RESISTANCE AS RPINELL HAPDNESS	110 - 140	110 - 146	110 - 140
RPINELL, HAPPINESS REQUIPED WELLTING AND	Conventional welding methods. No preheating.	Conventional welding methods. No preheating.	Conventional unlding methods. We graheating.
APINELL, HAPDNESS	Conventinual welding methods. No preheating. Mormal forming and cutting	Conventional welding methods. No preheating. Mormal forming and cutting	Conventional unlding methods. We preheating. Mormal forming and mitting
RPINELL, HAPPNESS REQUIPED WELLTING AND	Conventional welding methods. No preheating.	Conventional welding methods. No preheating.	Conventional unlding methods. We graheating.
RPINELL, HAPPNESS REQUIPED WELLTING AND	Conventinual welding methods. No preheating. Mormal forming and cutting	Conventional welding methods. No preheating. Mormal forming and cutting	Conventional unlding methods. We preheating. Mormal forming and mitting
RPIMELL, MARDNESS REQUIRED MELIDIMS AND PARRICATION TECHNIQUES	Conventional welding methods. No preheating. Mormal forming and cutting practice.	Conventional welding methods. No preheating. Mormal forming and cutting practice.	Conventional walding methods. We greheating. Hormal forming and outring practice.
RPINELL, HAPPNESS REQUIPED WELLTING AND	Conventinual welding methods. No preheating. Mormal forming and cutting	Conventional welding methods. No preheating. Mormal forming and cutting	Conventional unlding methods. We preheating. Mormal forming and mitting

TABLE 8-3.3 (Continued)

PROPERTIES OF STEELS USED FOR ICE-STREMOTHERS SKIPS

STEEL TYPE & GRADE	Bureau Veritas	MOCK	German Lloyd
	MS Gr. A Open-hearth, hasic-omygen,	MB Gr. KA Open-hearth, besic-cayyen,	MS Gr. A Open-hearth, besic-oxygen,
PROCESS OF MANUFACTURE	electric-furnace, or any	or electric-furnace	electric-furnace, or any
	equivalent approved by the	process, or other approved	equivalent approved by the
	society	by the society	Any method, except riseed
DECRIDATION	Not read., but rissed steel	Semi-killed or killed*	Any method, except rismed
HEAT TREATMENT	not above 12.5 MM (1/2 IM)	Not required	steel shove 12.5 HH(1/2 [H]
MAT THATMET	Not required	mot temption	Not required
CHEMICAL COMPOSITION (Ladie Analysis - %)			
Carbon (max.) Hanganese Phosphorus (max.) Sulphur (max.) Silicus Chromium Hickel Hilyblenus Copper Titanium Vanadium	0.05 0.05	0.23 2.5 m C min. 0.04 0.35 mam.	0.23 2.5 x C min.* 0.04 0.35 max.
Aluminum Others Notes:	*Manganese content not to be less than 2-1/2 times the carbon content for	*Rimmed steel is accepted for plates up to 12.5 MM [1/2 TM] inclusive.	*Manganese content may be less below 12.5 MM (1/2 1M).
	nore than 12.5 MM (1/2 IN).	1772 IN THE LUNIVE.	11/2 11/7
TEMSILE REQUIREMENTS Ultimate NG/MM ² (RSI) Yield (min.)NG/MM ² (RSI) Slongation (min.) 4 in 5.65 yR MM (IM) or as noted (Awares of spe.)	41 ~ 50 (50 ~ 71) 24 (34) 22	41 - 50 (58 - 71) 24 (34) 22	41 - 50 (58 - 71) 24 (34) 22
CHARPY V-MOTCH IMPACT TEST Temperature *C Energy, KG-M (FT-LB)	None required	None required	None required
NEW TEMPERATURE *C			
DYNAMIC TEAR EMERTY IN EG-M (PT-LR) AT 24°C POR 16 MM (5/0 LM) THICK SPECIMEN			
ABRASIIM RESISTANCE AS BRINELL HARLMESS	110 - 140	110 - 140	110 - 140
PEGITIED WELDING AND PARTICATION TECHNIQUES	Conventional welding methods. No preheating. Mormal forming and cutting practice.	Conventional welding methods. He proheating. Hormal forming and cutting practice.	Conventional welding methods. No probesting. Normal forming and cutting practice.
MELATIVE COST PACTOR These I on ARS Stade A)	1.0	1.0	1.0
	•	1	1

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	ADS MG Gr. D	Lloyd's Register MS Gr. 8	Horste Verites MS Gr. NVB
	Open-hearth, basic-oxygen,	Open-hearth, electric-	Open-hearth, basic-oxygen,
PROCESS OF MANUFACTURE	electric-furnace, vacuum-	furnace, or heatc-oxygen	or electric-furnace groces
	arc remelt, or electro-	process	
	slee remait process		
DECKIDATION	Any method, except rimmed	Any method, except rimmed	Any method, except rimmed
HEAT TREATMENT	steel	steel	steel
Mat talkingst	Not required	Not required The sum of carbon content	Not required Carbon plus 1/6 of the
CHENICAL COMPOSITION	The carbon content + 1/6 of		manganese content is not to
(Ladie Amelysis - %)	the mangamese content is	content shall not exceed	exceed 0.40%.
	not to exceed 0.40%. If	0.401.	
	this condition is		1
	matimfied, manganese may	Į.	
	be up to 1.65%.		
Carbon (max.)	0.21	9.21	0.21
Manganese	0.80 - 1.10*	9.80 min.*	0.80*
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.)	0.04	0.04	0.04
Silicon	0.35 max.	0.50 max.	0.35 max.
Chromium			!
Wickel	I		1
Mož ybdenum Copper	1		i
Copper Titenium	į .		
Venedium	l		
Aluminum	l		
Others	ĺ	,	
	}		
Motes:	*8.60 min. for fully	*If silicon content is	*If milicon content is
	hilled or cold flanging	0.10 or more, min.	0.10, min. mengenese
	quality.	Manganese may be 0.60.	may be reduced to 0.60%.
	i .		
	l		
TUMBILE REQUIREMENTS Ultimate MG/MH ² (MSI) Tield (min.)MG/MH ² (MSI)	41 - 50 (50 - 71) 24 (34)	41 - 50 (56 - 71) 24 (14)	41 - 50 (50 - 71) 24 (34)
Elongation (min.) % in	21 in 200 NH (8 IN) or 24	22 (34)	22 (34)
5.65 38 MM (IN) or as	in 50 MM (2 IN)		
noted (A-area of spe.)	9		
CHARPY V-HOTCH IMPACT	Required for thicknesses	Required for thicknesses	
TEST	above 25 MM (1 IN) only	above 25 MM (1 IN) only	
Temperature *C	0	0	0
Energy, EG-M (FT-LB)	2.8 (20) Longitudinal	2.8 (20) Longitudinal	2.8 (20) Longitudinel
,	2.0 (14) Transverse		2.0 (14) Transverse
NOT TEMPERATURE *C	+10 to + 16		
	<u> </u>		
DYNAMIC TEAR BRERGY IN RG-H (FT-LB) AT 24°C	1		
IN RG-M (FT-LB) AT 24°C FOR 16 MM (5/0 IN)	46 (333)		
THICK SPECIMEN	1 40 (333)		
	<u> </u>		
ABRASION RESISTANCE AS BRINELL MARDNESS	110 - 140	110 - 140	110 - 140
BRIMELL MARINESS	1		
	Conventional welding		
REQUIRED WELDING AND	methods. No preheating.	Conventional walding	Conventional walding
FARRICATION TECHNIQUES	Normal forming and cutting	methods. No preheating.	methods. No preheating.
	practice.	Mormal forming and cutting	Mormal forming and cutting practice.
	l	practice.	prestice.
			
PELATIVE CHST FACTOR	1.015	1.015	1.015
(Based on ARS Grade A)	1		
	1	l	I

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	Bureau Veritae MS Gr. B	Milk Co. To	German, Lloyd
	Open-hearth, besic-emygen,	MB Gr. EB Open-hearth, besic-cayess,	MS Gr. B Open-hearth, besic-oxygen,
PROCESS OF MANUFACTURE	electric-furnace, or any	or electric-furnece	electric-furnece, or env
	equivalent approved by the	process, or other approved	equivalent approved by the
	acciety	by the sectety	society
DBOKIDATION	Rissed steel not to be	Semi-killed or killed	Any method, except rismed
HEAT THEATHERT	Mot required	Not required	steel Not required
CHEMICAL COMPOSITION (Ladle Analysis - %)			
Carbon (mex.) Manganese	0.21 0.00 - 1.46	0.21 0.00 min.	0.21 0.80 min.
Phosphorus (max.)	0.05	0.04	9.04
Sulphur (max.)	0.05	0.04	9.04
Silicon	0.35 max.	0.35 max.	0.35 max.
Chromium . Nickel			
Moj Apqeura			
Copper			
Titanium	1		
Venedium		Į i	
Al um i num			
Rhers			
Motes:			i
#//			
THREILS REQUIREMENTS Ultimate MG/M01 ² (MS1) Yield (min.) MG/M0 ² (RS1) Elongation (min.) % in 5.65 $\gamma \overline{\Lambda}^{*}$ MM (IM) or an noted (A-area of spe.)	41 - 30 (58 - 71) 24 (34) 22	41 - 50 (50 - 71) 24 (34) 22	41 - 50 (50 - 71) 24 (34) 22
CHARPY V-NOTCH IMPACT	None required		
Temperature °C	1	•	
Energy, KG-H (FT-LB)	Ĭ	2.8 (20) Longitudinal	2.8 (20) Longitudinal
		2.1 (15) Transverse	<u> </u>
MYT TEMPERATURE *C			
			
DYNAMIC TEAR ENERGY IN MG-M (FT-LB) AT 24°C POR 16 MM (5/8 IN) THICK SPECIMEN			
ARRASION RESISTANCE AS DRINELL HAPIMESS	110 - 140	110 - 140	110 - 140
MEGIIFED MELDING AND PARRICATION TRUMIQUES	Conventional welding methods. No probesting. Hormal forming and cutting practice.	Conventional welding methods. No proheating. Mormal forming and cutting practice.	Conventional umlding methods. Wo preheating. Mormal forming and cutting practice.
PREATEVE CHRT PACTUR Channel on ARS Grade As	1.015	1.015	1.615
	I		I

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	ADS MS Gr. DS	ARS	Lloyd's Register
	Open-hearth, hemic-oxygen,	NTS Gr. AM32 Open-hearth, heatc-oxygen,	NTS Gr. AN278
PROCESS OF HAMUFACTURE	electric-furnace, vacuum-	or electric-furnece	Open-hearth, electric- furnace, or hasic-oxygen
	arc remeit, or electro-	process	process
	slag remelt process		
PEOXIDATION	Fully killed, fine grain practice	Semi-killed or killed	Semi-killed or silicon-
HEAT TREATMENT	Hormalized	Horad.above 35 HH(1.38 IN)4	killed Normd.above 35 MM(1.38 IN)
	<u> </u>	Normd.above 12.5HM(1/21H)**	101-01-0000 33 101(11311 211)
	The carbon content + 1/6		
CHEMICAL COMPOSITION (Ladle Analysis - %)	of the manganese content is not to exceed 0.40%.		
	If this condition is		
	satisfied, mulganese may		
	be up to 1.65%.		
Carbon (max.)	0.16	0.18	0.18
Manganese	1.0 - 1.35	0.90 - 1.60***	0.70 - 1.60
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.) Silicon	0.04 0.10 - 0.35	0.04	0.04
Chromium	". IA - 9. 35	0.10 - 0.50 0.25 max.	0.05 max. 0.20 max.
Mickel	ì	0.40 max.	0.20 max.
No i ybdenus	l	0.08 max.	0.08 man.
Copper Titenium		0.35 max.	0.35 max.
Titanium Venedium		0.10 max.	0.03 - 0.10
Aluminum	i	U. 10 ==x.	0.015 min.
Others		0.05 max. Cb	0.015 - 0.05 16
Moten:			
myten;	ì	*If aluminum-treated. **If columbium or venedium	*Nbove 12.5 NM (1/2 IM), if miobium or aluminum
		practice used.	+ niobium prectice is used.
		***12.5 MM (1/2 IN) and	
		under may have min.	
		mangenese of 0.76%.	
TENSILE REQUIREMENTS			
Ultimate NG/194 ² (KSI)	41 - 50 (58 - 71)	48 - 60 (68 - 85)	41 - 52 (50 - 74)
Tield (min.) RG/1012 (RSI)		32 (45.5)	27 (30.5)
Elongation (min.) % in 5.65 % (IN) or as	21 in 200 NM (0 1M) or 24 in 50 MM (2 IM)	19 in 200 MM (8 IN) or 22 in 50 MM (2 IN)	22
noted (A=area of spe.)	24 1H 30 HH (2 1H)	22 In 50 MM (2 IN)	
CHARPY V-NOTCH IMPACT	Hone required		
TEST	nove tedrites	None required	Required for thicknesses above 12.5 MM (1/2 IN) only
Temperature *C			0
Energy, EG-M (FT-LB)			2.8 (20) Longitudinal
NOT TEMPERATURE *C		-12 to -7	
DYNAMIC TEAR EMERGY IN NG-N (PT-LB) AT 24°C			
FOR 16 NM (5/8 IN)		14 (101)	
THICK SPECIMEN	i	,	
ABRASION RESISTANCE AS	110 - 140	135 - 170	110 - 147
BRINELL HARDNESS	110 - 140	133 - 170	110 - 147
	<u></u>		
RECUIRED WELDING AND	Conventional welding	Moderate preheat for	Moderate preheat for
PARTICATION TECHNICUES	methods. Ho preheating.	welding. Low hydrogen	walding. Low-hydrogen
	Normal forming and cutting	practice. Hormal forming	practice. Hormal forming
	practice.	and cutting practice.	and cutting practice.
	 		
HELATIVE CHET FACTOR	1.04	1.11	1.11
(Besed on ARS Grade A)			•
	1	i i	

TABLE 8-3.3 (Continued)
PROPERTIES OF STREES USED FOR ICE-STRENGTHENED SHIPS

STEEL TYPE & GRADE	Lloyd's Register	Norske Veritas	Norske Verites
	NTS Gr. AN32	HTS Gr. NVA 278	HTS Gr. WVA32
	Open-hearth, electric-	Open-hearth, hasic-oxygen,	Open-hearth, hasic-oxygen,
PROCESS OF MAMUFACTURE	furnace, or besic-oxygen	or electric-furnace	or electric-furnace
	process	process	process
DECKIDATION	Semi-killed or silicon-	Semi-killed or fully killed	Fully killed
HEAT TREATMENT	Morad.above 35 MM(1.38 IN)	Not required	Hormalized
CHEMICAL COMPOSITION (Ladle Analysis - %)			
Carbon (max.) Manganese Phosphorus (max.)	0.18 0.70 - 16.0 0.04	0.20 0.70 min. 0.04	0.18 0.9 - 1.6* 0.04
Sulphur (mex.)	0.04	0.04	0.04
Silicon	0.05 max.		0.10 - 0.50
Chromium	9.20 max.	0.20 max.	0.20 max.
Hickel	0.40 max.	0.40 max.	0.40 max.
Mol yhdenun	0.08 max.	0.08 max.	0.00 max.
Copper Titenium	0.35 max.	0.35 max.	0.35 max.
Titanium Vanadium	0.03 - 0.10	0.10 max.	0.10 max.
Aluminum	0.015 min.	0.08 max.	0.10 max.
Others	0.015 - 0.05 Nb	0.05 max. 16b	0.05 rax. 46
Notes:	*Above 12.5 MM (1/2 IN), if miobium or aluminum + niobium practice in uned.		*0.70 min. may be used for 12.5 MM (1/2 IN) and less.
TEMBILE REQUIREMENTS Ultimate MG/MP ² (MS1) vield (min.) NG/MP ² (MS1) Elongation (min.) % in 5.65 /R MM (1M) or an noted (A-area of spe.)	45 - 60 (64 - 85) 32 (45-5) 22	41 - 52 (58 - 74) 27 (38-5) 22	45 - 60 (64 - 85) 32 (45-5) 22
CHARPY V-HOTCH IMPACT TEST Temperature °C Energy, KG-M (PT-LB)	Required for thicknesses above 12.5 MM (1/2 IN) only 0 3.16 (23) Longitudinal	Mone required	0 3.16 (23) Longitudinal 2.24 (16) Transverse
NOT TEMPERATURE °C			
DYNAMIC TEAR EMERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) TWICK SPECIMEN			
ABRASION MESISTANCE AS BRINELI, MARDNESS	125 - 170	110 - 147	175 - 170
REQUIRED WELDING AND PARTICATION TECHNIQUES	Moderate preheat for welding. Low-hydrogen practice. Normal forming and cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Mormal forming and cutting practice.	Moderate prohest for welding. Inw-hydrogen practice. Normal forming and cutting practice.
HERE THE PATENT HAS TRAINE A)	1.11	1,11	1.11

TABLE 8-3.3 (Continued)
PROPERTIES OF STEELS USED FOR ICE-STRENGTHENED SHIPS

STEEL TYPE & GRADE	Bureau Veritas	HKK	German. Lloyd
	HTS Gr. AH32	MTS Gr. KA32	HTS Gr. A32
	Open-hearth, hasic-oxygen,		Open-hearth, basic-oxygen
PROCESS OF MANUFACTURE	electric-furnace or any	or electric-furnace	electric-furnace or any
	equivalent approved by the society	process, or other approved	equivalent approved by th
DECKIDATION	Unrimmed steel, killed	hy the society Killed	society Killed
	above 12.5 MM (1/2 IN)	1	kili a d
HEAT TREATMENT	Not required*	Mormalized	Normalized
CHEMICAL COMPOSITION	1		
(Ladle Analysis - %)			Ĭ
Carbon (max.)	0.18	0.10	0.18
Manganese	0.70 - 1.60 **	0.90 - 1.60	0.90 - 1.60*
Phosphorus (max.) Sulphur (max.)	0.04	0.04	0.04
Silicon	0.04	0.04	0.04
Chromium	0.05 max. *** 0.20 max.	0.10 - 0.50	0.10 - 0.50
Nickel	0.20 max.	0.20 max. 0.40 max.	0.20 max.
Not ybdenum	0.00 max.	0.40 max. 0.00 max.	0.40 max.
Copper	0.35 max.	0.0A max. 0.35 max.	0.DR max.
Titanium	U-32 Mex.	T.35 Max.	0.35 max.
Veneritum	0.10 max.	ł	
Aluminum	0.06 max.	0.015 min.	0.07 max.
(Rhers	0.05 max. Nb	n.ata mtu.	D.U/ MAX.
Hates:	*Not required, if aluminum		*Minimum is 0.70 below
	or vanadium treated.	ĺ	12.5 MM (1/2 IN).
	**0.98-1.60 above 12.5 MM		1207 44 (1/2 14/4
	11/2 IN1.		
	***0.10-0.50 above 12.5 MM		
	(1/2 IN).	i	
TENSILE REQUIREMENTS			
Ultimate RG/MM ² (KSI)	45 - 60 (64 - 85)	48 - 60 (68 - 85)	48 - 60 (68 - 85)
Vield (min.) RG/1012 (RS1)	.32 (45.5)	32 (45.5)	32 (45.5)
Blongetion (min.) % in	20	22	22
5.65 A MM (IN) or as		••	••
noted (A-area of spe.)			
CHARPY V-HOTCH IMPACT	None required		
TRST	, .		1
Temperature *C		0	0
Bnergy, KG-M (PT-LB)) .	3.2 (23) Longitudinal	3.2 (23) Longitudinal
		2.3 (17) Transverse	2.2 (16) Transverse
MOT TEMPERATURE °C			
DYNAMIC TEAR ENERGY			
IN NG-M (FT-LB) AT 24°C			
POR 16 MM (5/8 IN)			
THICK SPECIMEN			
ADRASION RESISTANCE AS	125 - 170	135 - 170	125 - 170
DRIWELL MARINESS			
	Moderate preheat for	Moderate preheat for	Moderate preheat for
RECENTRED WELLSTAG AMP		welding. Low-hydrogen	welding. Low-hydrogen
REQUIRED WELDING AND PARTICATION TROUBLES	welding, tow-huderwes		second a mesmacelare code of
	welding. Low-hydrogen	practice. Mornel forming	practice. Myrmal forming
	practice. Normal forming	practice. Normal forming	practice. Hormal forming
	welding. Low-hydrogen practice. Mormal forming and cutting practice.	practice. Normal forming and cutting practice.	practice. Mormal forming and cutting practice.
REQUIRED MELDING AND PARRICATION TECHNIQUES	practice. Normal forming and cutting practice.	practice. Normal forming	practice. Normal forming and cutting practice.
PARTICATION TROUNTQUES	practice. Normal forming and cutting practice.	practice. Normal forming and cutting practice.	practice. Mormal forming and cutting practice.

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	ABS	Lloyd's Register	Lloyd's Register
STEEL TYPE & GRADE	NTS Gr. ANG	HTS Gr. AN345	MTS Gr. AN36
	Open-hearth, besic-oxygen,	Open-hearth, electric-	Open-hearth, electric-
PROCESS OF MAINIFACTURE	or electric-furnace process	furnace, or basic-oxygen	furnace, or basic-oxygen
		process	process
DECKIDATION	Semi-killed or killed	Semi-killed or silicon-	Semi-killed or silicon-
HEAT THEATMENT	Horad.above 35 HM(1.30 IN)	Milled Mored, above 35 MM(1.38 IM)4	Mormi,above 35 MM(1,38 IN)4
HEAT THEATMENT	Norma.above 35 MM(1.30 IM)	mored.above 35 mm(1.36 [m/-	MOTHAL 480VE 35 MM(1.36 IN)
CHEMICAL COMPOSITION (Ladle Analysis - %)			
Charle Milliyers	Ì		
		•	
	ĺ		
Carbon (max.)	0.18	0.10	0.18
Manganese Phosphorus (max.)	0.90 - 1.60***	070 - 1.60 0.04	070 - 1.60 0-04
Sulphur (max.)	9.04	0.04	0.04
Silicon	0.10 - 0.50	0.05 max.	0.05 max.
Chromium	0.25 max.	0.20 max.	0.20 max.
Nickel	0.40 max.	0.40 mex.	0.40 max.
Mol ybdenum	0.08 max.	0.08 max.	0.08 max.
Copper Titanium	0.35 max.	0.35 max.	0.35 max.
Titanium Vanadium	0.10 max.	0.03 - 0.10	0.03 - 0.10
Aluminum		0.015 min.	0.015 min.
Others	0.05 max. Cb	0.015 - 0.05 Mb	0.015 - 0.05 46
	J		•
Notes:	*If aluminum treated.	*Above 12.5 HH (1/2 IH),	*Ahove 12.5 MM (1/2 IM),
	**If columbium or vanadium practice used.	if niobium or aluminum + niobium practice is	if niobium or aluminum + niobium practice is
	***12.5 MM (1/2 IN) and	vmed.	used.
	under may have min.		
	manganese of 0.70%.		į
		L	
TENSILE REQUIREMENTS	(
Ultimate KG/MM ² (KSI)	50 - 61 (71 - 90)	62 (88)	50 - 63 (71 - 90) 36 (51)
Yield (min.)KG/MM ² (KSI)	36 (51) 19 in 200 MM (B IN) or	34 (48) 22	21
5.65 A MM (EN) or as	22 in 50 MM (2 IN)	**	•
noted (Ameres of spe.)	22 211 30 1111 (2 211)		
			
CHARPY V-NOTCH IMPACT	None required	Required for thicknesses	Required for thicknesses
TEST	1	above 12.5 MM (1/2 IN) only	above 12.5 HM (1/2 IN) only
Temperature °C	1		0
Energy, KG-M (FT-LB)	1	3.47 (25) Longitudinal	3.47 (25) Longitudinal
	 		
HIT TEMPERATURE °C	-12 to -7		
DYNAMIC TEAR ENERGY	1		
IN KG-M (FT-LB) AT 24°C	i	1	1
POR 16 MM (5/8 IN)	1	!	Į.
THICK SPECIMEN	1		
		177	140 - 181
ABRASION RESISTANCE AS	140 - 161	1 '''	1 140 - 181
		Į.	1
ARTHELL, HAPINESS		1	
BRINELL, HAPIMESS	Moderate preheat for	Moderate preheat for	Moderate prohest for
PEQUIRED WELDING AMD	welding. Low-hydrogen	welding. Low-hydrogen	Moderate prohest for welding. Low-hydrogen
	welding. Low-hydrogen practice. Hormal forming	welding. Low-hydrogen practice. Normal forming	welding. Low-hydrogen practice. Hormal forming
PEQUIRED WELDING AND	welding. Low-hydrogen	welding. Low-hydrogen	Hoderate prohest for welding, Low-hydrogen practice, Normal forming & cutting practice.
PEQUIRED WELDING AND	welding. Low-hydrogen practice. Hormal forming	welding. Low-hydrogen practice. Normal forming	welding. Low-hydrogen practice. Hormal forming
PECHINED WELDING AND PARRICATION TECHNIQUES	welding. Low-hydrogen practice. Normal forming and cutting practice.	welding. Low-hydrogen practice. Mormal forming 6 cutting practice.	welding. Low-hydrogen practice. Hormal forming
PEQUIRED WELDING AND	welding. Low-hydrogen practice. Hormal forming	welding. Low-hydrogen practice. Normal forming	welding. Low-hydrogen practice. Normal forming 6 cutting practice.

TABLE B-3.3 (Continued)

	STEEL TYPE & GRADE		T	
	STEEL TYPE & GRADE	Norske Veritas	Norske Veritas	Bureau Veritas
		HTS Gr. NVA 36	HTS Gr. NVA40S	HTS Gr. AH36
		Open-hearth, hasic-oxygen,	Open-hearth, hasic-oxygen,	Open-hearth, hasic-oxygen,
	PROCESS OF MANUFACTURE	or electric-furnace	or electric-furnace	electric-furnace, or any
		process	process	equivalent approved by
	l	1 .	1	the society
	DEOXIDATION	Fully killed	Fully killed	Unrimmed steel, killed
	(1	(above 12.5 MM (1/2 IN)
	HEAT TREATMENT	Not required	Normd.above 12.5 MM(1/2 IN)	Not required
				HOC LEGUITED
	CHEMICAL COMPOSITION (Ladle Analysis - %)			
8-68	Carbon (max.) Manganese Phosphorus (max.) Sulphur (max.) Silicon Chromium Mickel Molybdenum Copper Titanium Vanadium Aluminum Others	0.18 0.9 - 1.6* 0.04 0.04 0.10 - 0.50 0.20 max. 0.40 max. 0.08 max. 0.35 max. 0.08 max. 0.08 max. 0.07 max. 0.08 max. 0.09 max.	0.18 0.9 - 1.6* 0.04 0.04 0.10 - 0.50 0.20 max. 0.40 max. 0.08 max. 0.10 max. 0.05 max. 0.05 max. 0.10 max.	0.18 0.70 - 1.60** 0.04 0.04 0.50 max.*** 0.20 max. 0.40 max. 0.40 max. 0.08 max. 0.10 max. 0.06 max. 0.06 max. 0.06 max. 0.07 max. 0.07 max. 0.08 max.
				0.90-1.60 above 12.5 MM (1/2 IN). *0.10-0.50 above 12.5 MM (1/2 IN).
	TEMBILE REQUIREMENTS Ultimate KG/MM ² (KSI) Vield (ain.)KG/MM ² (KSI) Elongation (ain.) % in 5.65 /K MM (IN) or as noted (A=area of spe.)	50 - 63 (71 - 90) 36 (51) 21	54 - 66 (77 - 94) 40 (57) 20	50 - 63 (71 - 90) 36 (51) 20
	CHARPY V-NOTCH IMPACT			None required
	Temperature °C Energy, KG-M (FT-LB)	0 3.47 (25) Longitudinal 2.45 (18) Transverse	0 4.0 (29) Longitudinal 2.65 (19) Transverse	
	NOT TEMPERATURE *C			
-69	DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN			
	ARRASION RESISTANCE AS BRINELL HARDNESS	140 - 181	153 - 190	140 - 181
	REQUIRED WELDING AND PARTICATION TECHNIQUES	Moderate preheat for welding. Low-hydrogen practice. Normal forming 6 cutting practice.	Mo/ rate preheat for we ding. Low-hydrogen practice. Hormal forming a cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Mormal forming & cutting practice.
	PF-ATIVE COST PACTOR (Beself on ABS Grade A)	1.17	1.17	1.17

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TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	T NKK	German, Lloyd	ARS
	HTS Gr. KA36	HTS Gr. A36	MS Gr. D
	Open-hearth, hasic-oxygen,	Open-hearth, basic-oxygen,	Open-hearth, basic-oxygen,
PROCESS OF MANUFACTURE	electric-furnace process,	elect-ic-furnace, or any	electric-furnace, vacuum-
	or other approved by the	equivalent approved by the	arc remelt, or electro-
	society	Rociety	slag remeit process
DECKIDATION	Killed	Killed	Fully killed, fine grain
HEAT TREATMENT	Normalized	Normalized	practice Normd.above 35 MM (1.38 IN)
HEAT TREATMENT	NOTWELLER OF	NOTHELIEGO	NOT MIC . BLOVE 35 HP (1:30 IN)
CHEMICAL COMPOSITION		l	The carbon content + 1/6
(Ladle Analysis ~ %)	l	[of the manganese content
		l	is not to exceed 0.40%.
		i	If this condition is
	l .		satisfied, manganese may
		<u>t</u>	be up to 1.65%.
Carbon (max.)	0.16	0.18	0.21
Manganese	0.90 - 1.60	0.90 - 1.60*	0.70 - 1.35*
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.)	0.04	0.04	0.04
Silicon	0.10 - 0.50	0.10 - 0.50	0.10 - 0.35
Chromium	0.20 max.	0.20 max.	!
Nickel	0.40 max. 0.00 max.	0.40 max.	1
Holybdenum Copper	0.08 max. 0.35 max.	0.00 max. 0.35 max.	1
Copper Titanium	U.35 MEX.	U.35 Max.	1
Vanadium	0.10 max.	0.10 max.	l
Aluminum	0.015 min.	0.07 max.	
Others	0.05 max. Nb	0.05 max. Nh	
]		
Notes:	1	*Minimum is 0.70 below	*0.60 min. for 25 MM (1 IN)
		12.50 MM (1/2 IN).	thickness and under.
	L	l	
		Į.	
	1	j]
	(
	1		
TENSILE REQUIREMENTS) .]	}
Ultimate KG/MM ² (KSI)	50 - 63 (71 - 90)	50 - 63 (71 - 90)	41 - 50 (58 - 71)
Yield (min.) KG/MM ² (KS1) Elongation (min.) % in		36 (51)	24 (34)
5.65 1A MM (IN) or as	21	21	21 in 200 MM (8 IN) or 24 in 50 MM (2 IN)
noted (Amarea of spe.)	1	i	24 10 50 MM (2 IN)
		<u> </u>	į
CHARPY V-NOTCH IMPACT		ł	Ì
TEST Temperature °C			-10
Energy, FG-M (PT-LB)	3.5 (25) Longitudinal	3.5 (25) Longitudinal	2.8 (20) Longitudinal
Energy, RO-A (FI-LB)	2.5 (18) Transverse	2.4 (17) Transverse	2.0 (14) Transverse
	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	100 100 1100	Tato (14) Italiavetae
NUT TEMPERATURE °C	1	}	~35 aver.
DYNAMIC TEAR ENERGY	 		
DYNAMIC TEAK EMERGY IN KG-M (FT-LB) AT 24°C	l	ł.	
FOR 16 MM (5/8 1N)	1	1	1
THICK SPECIMEN	I		1
	I	1	1
			T
ABRASION RESISTANCE AS	1	1	110 - 140
BRINELL HAHDNESS	140 - 181	140 - 191	
	Moderate preheat for	Moderate prehent for	Conventional welding
RECHIRED WELDING AND	welding. Low-hydrogen	moderate present for	methods. No preheating.
FARRICATION TECHNIQUES	practice. Normal forming	welding. Low-hydrogen practice. Normal forming	Normal forming and cutting
		& cutting practice.	practice.
· · ·	is cutting practice.		1 1 1 1 1 1 1 1 1
	% cutting practice.		İ
	& cutting practice.		
RELATIVE (DST PACTUR (Based on ABS Grade A)	6 cutting practice.	1.17	1.31

TABLE B-3.3 (Continued)

STEEL TYPE & GRADE	ABS	Lloyd's Register	Norske Verites
	MS Gr. CS Open-hearth, basic-oxygen,	MS Gr. D Open-hearth, electric-	MS Gr. NVD Open-hearth, hasic-oxygen,
PROCESS OF MANUFACTURE	electric-furnace, vacuum-	furnace, or basic-oxygen	or electric-furnace
	arc remelt, or electro- siag remelt process	process	process
DEOXIDATION	Fully killed, fine grain practice	Fully killed, fine grain practice	Any method except rimmed steel
HEAT TREATMENT	Normalized	Mormelized	Normd-above 25 MM (1 IN)*
CHEMICAL COMPOSITION	The carbon content + 1/6	l	
(Ladle Analysis - %)	of the manganese content	The sum of carbon content plus 1/6 of the manganese	Carbon plus 1/6 of the
(Correct Miles)	is not to exceed 0.40%.	content shall not exceed	to exceed 0.40%
	If this condition is	0.40%.	
	satisfied, manganese may be up to 1.65%.	ĺ	
	De 45 (1.631)		{
Carbon (max.)	0.16	0.21	0.21
Manganese Phosphorus (max.)	1.0 - 1.35 0.04	0.70 - 1.40*	0.60
Sulphur (max.)	0.04	0.04	0.04
Silicon	0.10 - 0.35	0.10 - 0.50 max.	0.35 max.
Chromium	1	0.10 - 0.30 mak.) max.
Nickel		1	
Not ybdenum	1		1
Copper	j	1	1
Titanium	1		
Vanadium Aluminum	l		1
Aluminum Others	ł	0.015 min.	l
ocher •	}	ì]
Notes:	ĺ	*For 25.5 MM (1 (N) or	*With fine grain practice
	I	less, min. mangenese may	normalizing is only
	i	be 0.60.	required for thicknessess
			ahove 35 MM (1.38 IN).
		,	}
TENSILE REQUIREMENTS			
Ultimate KG/MM ² (KSI)	41 - 50 (58 - 71)	41 - 50 (58 - 71)	41 - 50 (58 - 71)
Yield (min.)KG/MM ² (KSI)		24 (34)	24 (34)
Elongation (min.) % in 5.65 (A MM (IN) or am	21 in 200 MM (8 IN) or	}	22
noted (A=area of spe.)	24 in 50 MM (2 IN)	22	
CHARPY V-NOTCH IMPACT TEST	None required	Į	
TEST Temperature °C	l	ا م	-10
Energy, KG-M (FT-LB)	l	4.8 (35) Longitudina)	2.75 (20) Longitudinal
			2.0 (14) Transverse
NUT TEMPERATURE °C	-57 to -51		
DYNAMIC TEAM ENERGY			
IN KG-M (PT-LB) AT 24°C	98 (709)	}	}
FOR 16 MM (5/8 IN) THICK SPECIMEN	1		l .
INICK SPECIMEN			
ABRASION RESISTANCE AS	110 - 140	110 - 140	110 - 140
BRINELL HARDNESS	} ··· ' **	110 - 100	1 - 140
	Conventior 41 welding	Conventional welding	Conventional welding
REQUIRED WELDING AND	methods. No preheating.	methods. No preheating.	methods. No preheating.
FABRICATION TECHNIQUES	Normal forming and cutting	Normal forming and cutting	
	practice.	practice.	practice.
HELATIVE COST FACTOR	l	.	1
(Based on ABS Grade A)	1.31	1.31] 1.31

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	Bureau Veritas MS Gr. D	NIKK MS Gr. KD	German. Lloyd MS Gr. D
PROCESS OF MARUPACTURE	Open-hearth, hasic-oxygen, electric-furnace, or any equivalent approved by the society	Open-hearth, hasic-oxygen, electric-furnace process, or other approved by the society	Open-hearth, basic-oxygen, electric-furnace process, or other approved by the society
DECKIDATION	Rimmed steel not be used	Semi-killed or killed*	Any method, except rimmed steel*
HEAT TREATHENT	Not required	Normd above 25 MM (1 IN)	Normd shove 25.5 NM (1 IN)
CHEMICAL COMPOSITION (Ladie Analysis - %)			
Carbon (max.) Manganese Phosphorus (max.) Sulphur (max.) Silicon Chromium Mickel Holyhdenum Copper	0.21 0.60 - 1.40 0.05 0.05 0.35 max.	0.21 0.60 min. 0.04 0.04 0.35 max.	0.21 0.70 - 1.40 0.04 0.04 0.10 - 0.15
Titenium Vanadium Aluminum Others			0.02 min.
Notes:		*Semi-killed is accepted for thickness up to 25 100 (1 (N) inclusive.	*A)uminum treated and fine grain practice above 25,5 MM (1 IM).
TENSILE REQUIREMENTS Ultimate RG/NM ² (RSI) Yield (min.)RG/NM ² (RSI) Siongation (min.) % in 5.65 7/R NM (IM) or as noted (A-area of Spe.)	41 - 50 (58 - 71) 24 (34) 22	41 - 50 (58 - 71) 24 (34) 22	41 - 50 (50 - 71) 26 (34) 22
CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, EG-N (FT-LB)	0 4.8 (35) Longitudinal	-10 2.8 (20) Longitudinal 2.1 (15) Trangverse	- 20 2.8 (20) Longitudinal
NOT TEMPERATURE *C			
DYNAMIC TEAR EMERGY IN RG-M (PT-LB) AT 24°C POR 16 RM (5/8 IN) THICK SPECIMEN			
ABRASION RESISTANCE AS BRINELL MARLNESS	110 - 140	110 - 140	110 - 140
REQUIRED WELDING AND PARRICATION TECHNIQUES	Conventional welding methods. No preheating. Normal forming and cutting practice.	Conventional welding methods. No preheating. Normal forming and cutting practice.	Conventional welding methods. No preheating. Normal forming and cutting practice.
RELATIVE COST FACTOR (Based on ARS Grade A)	1.31	1.31	1.31

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	ABS MS Gr. B	Lloyd's Register	Morake Verites MS Gr. MVE
	Open-hearth, basic-naygen,	Open-hearth, electric-	Open-hearth, hesic-oxygen,
PROCESS OF MANUFACTURE	electric-furnace, vacuum-	furnace, or basic-oxygen	or electric-furnace proces
	arc remeit, or electro-	process	
	slag remelt process		
DECKIDATION	Fully killed, fine grain	Fully killed, fine grain	Fully killed, fine grain
HEAT TREATMENT	Practice Normalized	practice Normalized	Practice Normalised
HAN I KANIMAN	The carbon content + 1/6	The sum of carbon content	Carbon plus 1/6 of the
CHEMICAL COMPOSITION	of the manganese content	plus 1/6 of the manganese	mangamese content is not
(Ladle Analysis - %)	is not to exceed 0.40%.	content shall not exceed	to exceed 0.40%.
, , ,	If this condition is	0.40%	
	matisfied, manganese may		
	be up to 1.65%.		
			1
Carbon (max.)	0.16	0.18	0.18
Manyanese	0.70 - 1.35	0.70 - 1.50	0.70
Phosphorum (max.)	0.04	0.04	0.04
Sulphur (max.)	0.04	0.04	0.04
Silicon	0.10 - 0.35	0.10 - 0.50	0.10 - 0.35
Christian	1		l
Nickel	}		1
Holybdenum			l
Copper	1		l
Titanium Vanadium			l
Vanadium Aluminum		0.045 -1-	
Aluminum (Athera		0.015 min.	0.915 min.
ta ners			
Wites:			
TEMBILE REQUIREMENTS Ultimate NG/MM ² (RS1) Yield (min.)NG/MM ² (RS1) Blompation (min.) % in 5.65 (Å MM (IN) or as	41 - 50 (50 - 71) 24 (14) 21 in 200 MM (8 IM) or 24 in 50 MM (2 IM)	41 - 50 (56 - 71) 24 (34) 22	41 - 50 (50 - 71) 24 (34) 22
noted (Amerea of upe.)			
CHARPY V-NOTCH IMPACT			1
TEST		1	
Temperature *C	-40	-40	-40
Energy, RG-H (PT-LB)	2.8 (20) Longitudinal	2.75 (20) Longitudinal	2.75 (20) Longitudinal
······································	2.0 (14) Transverse		2.0 (14) Transverse
NOT TEMPERATURE *C	-48 to -46		
DYNAMIC TEAR ENERGY			
IN NG-M (FT-LB) AT 24°C FOR 16 MM (5/R IN) THICK SPECIMEN			
ARRASIIM RESISTANCE AS ORINGLI, MARINESS	110 - 140	110 - 140	110 - 140
			<u> </u>
PEUTIFED WELDING AND PARFICATION TECHNIQUES	Conventional welding methods. No preheating, Hormal forming and cutting practice.	Conventional welding methods. No prohesting. Mormal forming and cutting practice.	Conventional welding methods. No preheating. Normal forming and cutting practice.
PELATIVE COST FACTOR Chase ton ABS Grade A)	1. 36	1.36	1.16

TABLE B-3.3 (Continued)

STEEL TYPE & GRADE	Bureau Veritas MS Gr. B	NEX MB Gr. KB	German. Lloyd MS Gr. S
PROCESS OF MAMIFACTURE	Open-hearth, basic-oxygen, electric-furnace, or any equivalent approved by the society	Open-hearth, basic-oxygen, electric-furnace process, or other approved by the society	Open-hearth, hesic-oxygen, electric-furnece, or any equivalent approved by the society
DECKIDATION	Fully killed, fine grain	Killed*	Aluminum treated, fine grain practice
HEAT TREATMENT	Mormelized	Normalized	Hormelized
CHEMICAL COMPOSITION (Ladle Analysis - %)			
Carbon (max.) Manganese Phosphorus (max.) Sulphur (max.) Silicon Chromium Mickel Molybdenum Copper	0.18 0.70 - 1.50 0.05 0.05 0.05	0.1R 0.70 min. 0.04 0.04 0.10 - 0.35	0.10 0.70 - 1.50 0.04 0.04 0.10 - 0.35
Coper Titanium Vanadium Aluminum Othera Hoten:	0.015 - 0.06	0.015 min. *Aluminum treatment is to be used as a fine grain practice.	0.02 min.
TEMSILE REQUIREMENTS Ultimate RG/Mm ² (RSI) Yield (min.)RG/Mm ² (RSI) Sicogation (min.) % in Sicos (min.) % in noted (A-area of spe.)	41 - 50 (58 - 71) 24 (34) 22	41 = 50 (58 = 71) 24 (34 · 22	41 - 50 (58 - 71) 24 (34) 22
CHARPY V-MOTCH EMPACT TEST Temperature °C Energy, KG-M (PT-LB)	-40 2.8 (20) Longitudinal	-40 2.8 (20) Longitudinal 2.1 (15) Transverse	~40 2.9 (20) Longitudinal
NUT TEMPERATURE °C			
DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN			
ABRASION RESISTANCE AS BRINELL HARONESS	110 - 140	110 - 140	110 - 140
REQUIRED MELDING AND PARPICATION TECHNIQUES	Conventional walding mathods. No preheating. Normal forming and cutting practice.	Conventional welding mathods. We preheating. Normal forming and cutting practice.	Conventional welding methods. No preheating. Mormal forming and cutting practice.
RELATIVE COST PACTOR (Based on ABS Grade A)	1 - 36	1.36	1-36

TABLE 8-3.3 (Continued)

PROCESS OF MANUPACTURE DECKIDATION REAT TREATMENT MEAT TREATMENT CMEMICAL COMPOSITION (Ladle Analysis - %) Carbon (max.) Manganese Phosphorus (max.) Silicon Chrimium Copper Titanium Vanadium Aluminum Others Motes: **Titalum **Titalum Vanadium Aluminum Others Motes: **Titalum urnace	ABS HTS Gr. DH36 Open-hearth, basic-oxygen, or electric-furnece	Lloyd's Register NTS Gr. DN278 Open-hearth, electric-	
PROCESS OF MANUFACTURE PROCESS OF MANUFACTURE DESCRIDATION Rilled, fine MEAT TREATMENT CHEMICAL COMPOSITION (Ladie Analysis - %) Carbon (MAX.) Manganese Phosphorus (MAX.) Silicon Chromium Mickel Molybdenum Copper Titanium Vanadium Aluminum Others Motes: **If aluminum **of columbis practice is: **Of aluminum **of aluminum **of columbis practice is: **Of aluminum **	urnace	Open-hearth, basic-oxygen,	Open-bearth, electric-
PROCESS OF MAMUPACTURE DECKIDATION Rilled, fine MEAT TREATMENT Mormd.ebove: 0.90 Monghorus (max.) 0.10 0.10	urnace		Open-bearth, alactric-
DECRIDATION Killed, fine MEAT TREATMENT Hornd.shove in Hornd.show in Ho			Open meeting espective
DECRIDATION Killed, fine MEAT TREATMENT Hornd.shove: CMEMICAL COMPOSITION (Ladle Analysis - %) Carbon (max.) Manganese 0.90 Phosphorus (max.) Silicon 0.10 Chromium 0. Mickel 0.01 Mickel 0.01 Mickel 0.01 Titanium Vanadium 0.01 Aluminum Others 0.07 Motes: "If aluminum "Fif columbis practice is: TEMBILE REQUIREMENTS Ultimate RO/NH2 (RSI) Tield (min.) RG/NH2 (RSI) THENT TEMPERATURE °C -22 (17) Train MOT TEMPERATURE °C -62 to DYNAMIC TEAR ENERGY IN RG-M (FF-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN REQUIRED WELDING AND FABRICATION TECHNIQUES Moderate prei welding. Low FABRICATION TECHNIQUES Moderate prei welding. Low FABRICATION TECHNIQUES Moderate prei welding. Low FABRICATION TECHNIQUES			furnace, or basic-oxygen
CARPOLICAL COMPOSITION (Ladle Analysis - %) Carbon (max.) (Manganese 0.90 Phosphorus (max.) Sulphur (max.) Sulphur (max.) Sulphur (max.) Sulphur (max.) Sulphur (max.) Sulphur (max.) Ochromium Hickel Mnlybdenum Copper Titanium Vanadium Aluminum Others Motes: *If aluminum **If columbin practice is: **If aluminum **If columbin **If columbin **If aluminum **If columbin **If aluminum **If columbin **If columbin **If aluminum **If columbin **If columbin **If aluminum **If alu		process	process
CARPOLICAL COMPOSITION (Ladle Analysis - %) Carbon (max.) (Manganese 0.90 Phosphorus (max.) Sulphur (max.) Sulphur (max.) Sulphur (max.) Sulphur (max.) Sulphur (max.) Sulphur (max.) Ochromium Hickel Mnlybdenum Copper Titanium Vanadium Aluminum Others Motes: *If aluminum **If columbin practice is: **If aluminum **If columbin **If columbin **If aluminum **If columbin **If aluminum **If columbin **If columbin **If aluminum **If columbin **If columbin **If aluminum **If alu			Ĺ
CARDON (MAX.) Carbon (MAX.) Manganese 0.90 Phosphorus (MAX.) Silicon 0.10 Chromium 0. Mickel 0.0 Mickel 0.0 Mickel 0.0 Copper 0.0 Titanium 0.0 Aluminum 0.0 Aluminum 0.0 Aluminum 0.0 Motes: "If aluminum origi columbin practice is in the colu	grain practice	Killed, fine grain practice	
CARDON (MAX.) Carbon (MAX.) Manganese 0.90 Phosphorus (MAX.) Silicon 0.10 Chromium 0. Mickel 0.0 Mickel 0.0 Mickel 0.0 Copper 0.0 Titanium 0.0 Aluminum 0.0 Aluminum 0.0 Aluminum 0.0 Motes: "If aluminum origi columbin practice is in the colu			killed
CARDON (MAX.) Carbon (MAX.) Manganese 0.90 Phosphorus (MAX.) Silicon 0.10 Chromium 0. Mickel 0.0 Mickel 0.0 Mickel 0.0 Copper 0.0 Titanium 0.0 Aluminum 0.0 Aluminum 0.0 Aluminum 0.0 Motes: "If aluminum origi columbin practice is in the colu	5.5 MM(1 IN)*	Normd.above 25.5 HM(1 IN)*	Morad.above 25.5 MM (1 IN)
CARDON (MAX.) Carbon (MAX.) Manganese 0.90 Phosphorus (MAX.) Silicon 0.10 Chromium 0. Mickel 0.0 Mickel 0.0 Mickel 0.0 Copper 0.0 Titanium 0.0 Aluminum 0.0 Aluminum 0.0 Aluminum 0.0 Motes: "If aluminum origi columbin practice is in the colu	2.5886(1/2IH)+4	Normd.above 12.588(1/218)*4	
Carbon (max.) Carbon (max.) Manganese Phosphorus (max.) Sulphur (max.) Sulphur (max.) Silicon Chromius Mickel Milybdenum Copper Titanius Vanadius Aluminum Others Motes: *If aluminum *If columbin practice is: *If aluminum *If columbin *If aluminum *If columbin *If aluminum *If columbin practice is: *If aluminum *If columbin *If columbin *If columbin *If columbin *If columbin *If aluminum *If columbin			
Carbon (MAX.) Manganese O.90 Phosphorus (MAX.) Silicon O.10 Chromium O. Mickel Milybdenum O. Copper Titanium Vanadium Aluminum Others Motes: *If aluminum Others Motes: *If aluminum **If columbin practice is in **If aluminum **If columbin	1		•
Carbon (MAX.) Manganese Phosphorus (MAX.) Silicon Silicon Chromium Chers Motea: **If aluminum Others Motea: **If aluminum **If columbing practice is in the columbing practice is in the columbing practice is in the columbin	ì	i i	
Manganese Phosphorus (max.) Silicon 0.10 Chromium 0. Mickel 0. Mic			
Manganese 0.90 Phosphorus (max.) 0. Sulphur (max.) 0. Sulphur (max.) 0. Silicon 0.10 Chromium 0. Mickel 0.0 Mi			
Manganese Phosphorus (max.) Silicon 0.10 Chromium 0. Mickel 0. Mic	Į.		
Manganese Phosphorus (max.) Silicon Silicon O.10 Chromium O.Wickel Molybdenum O.Dopper Titanium Vanadium Aluminum Others Motes: **If aluminum **If columbis* practice is: **If aluminum **If columbis* **	i		
Manganese Phosphorus (max.) Silicon Silicon O.10 Chromium Mickel O.10 Chyper Titanium Vanadium Aluminum ORhers Motes: **If aluminum ORhers Ultimate RO/NH2 (RSI) Tield (min.)RG/NH2 (RSI) Tield (m	i		
Manganese Phosphorus (max.) Silicon Silicon O.10 Chromium Mickel O.10 Chyper Titanium Vanadium Aluminum ORhers Motes: **If aluminum ORhers Ultimate RO/NH2 (RSI) Tield (min.)RG/NH2 (RSI) Tield (m	!		
Phosphorus (mex.) Sulphur (mex.) Sulphur (mex.) Silicon Chromium Onichel Mickel Milybdenum Copper Titanium Vanadium Aluminum Others Motes: TEMBILE REQUIREMENTS Ultimate RG/MM ² (KSI) Field (min.) RG/MW ² (KSI) Field (min.) RG/MW ² (KSI) Field (min.) NG/MW ² (KSI) Field (min.) NG/MW ² (KSI) Field (min.) On an noted (Amarea of spe.) CHARPY V-NOTCH IMPACT TEST TEMPLE RGM (FT-LB) TEMPLE AT COLUMBIA W/T TEMPERATURE °C DYNAMIC TEAR EMERGY IN RG-M (FT-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN REQUIRED WELDING AND FABRICATION TECHNIQUES Moderate preived lang. Longerice. Moderate preived lang. Longerice.		0.1A	0.18
Bulphur (max.) Silicon 0.10 Chrimdium 0.0 Mickel 0.0 M		0.90 - 1.60	0.70 - 1.60
Silicon Chromium Mickel Mnlybdenum Copper Titanium Vanadium Aluminum Others Motes: **If aluminum ***If columbin **practice ls : **If aluminum ***If columbin ***practice ls : ***If aluminum ***If columbin ***If columbin ***If aluminum ***If columbin **If columbin ***If colum		0.04	0.04
Chromium Nickel Nickel Notes: Oppor Titanium Vanadium Aluminum Others Motes: *If aluminum *If aluminum *If columbing practice is is *If aluminum *If aluminum *If columbing practice is is *If aluminum *If aluminum *If aluminum *If aluminum *If columbing practice is is *If aluminum *If columbing *If columbing *If aluminum *If columbing *If c	04 j	0.04	0.04
Mickel Milybdenum Copper Titanium Vanadium Aluminum Others Motes: *If aluminum **If columbin practice is i *If aluminum **If columbin **If aluminum **If columbinum **If columbinum **If columbinum **If aluminum **If columbin	- 0.50	0.10 - 0.50	0.05 mags.
Mickel Milybdenum Copper Titanium Vanadium Aluminum Others Motes: *If aluminum **If columbin practice is i *If aluminum **If columbin **If aluminum **If columbinum **If columbinum **If columbinum **If aluminum **If columbin	25 max.	0.25 max.	0.20 max.
Mnlybdenum Copper Titanium Vanadium Aluminum Others Motes: *If aluminum **if columbin practice is i **if aluminum **if columbin practice is i **if aluminum **if columbin practice is i **if columbin **i	40 max.	0.40 max.	0.40 max.
COpper Titanium Vanadium Aluminum Others Motes: *If aluminum **If columbin **If columbin practice is: **If aluminum **If columbin **If colum	ne max.	0.00 max.	0.08 max.
Titanium Vanadium Aluminum Others Notes: *If aluminum *If columbin practice is i *If aluminum *If columbin *If colu	35 max.	0.00 max.	0.35 max.
Venedium Aluminum Others Motes: *If aluminum **if columbin **if columbin practice is if *If aluminum **if columbin **if colum	27 Max.	U.JD Mex.	U. 35 MAX.
Aluminum Others Others Motes: *If aluminum *If columbin practice is: *If aluminum *If columbin *If	1]	1
TEMBILE REQUIREMENTS Ultimate RC/NO2 (REI) Vield (min.) % (Min.) % (REI) Vield (min.) % (M	10 Max.	0.10 max.	0.03 - 0.10
Motes: *If aluminum **if columbis practice is s *if columbis practice is s *if columbis practice is s *if columbis **if columbi			0.015 min.
TEMBILE REQUIREMENTS Ultimate RC/NO2 (RSI) Vield (sin.) NC/NO2 (RSI) Plongation (sin.) % in 22 in 50 CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, KG-M (FT-LB) NOT TEMPERATURE °C OTHAMIC TEAR ENERGY IN KG-M (FF-LB) AT 24°C FOR 16 NM (5/D IN) THICK SPECIMEN REQUIRED WELDING AND FABRICATION TECHNIQUES REQUIRED WELDING AND FABRICATION TECHNIQUES	05 max. Cb	0.05 max. Cb	0.015 - 0.05 Mb
TEMBILE REQUIREMENTS Ultimate RC/NO2 (RSI) Vield (sin.) NC/NO2 (RSI) Plongation (sin.) % in 22 in 50 CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, KG-M (FT-LB) NOT TEMPERATURE °C OTHAMIC TEAR ENERGY IN KG-M (FF-LB) AT 24°C FOR 16 NM (5/D IN) THICK SPECIMEN REQUIRED WELDING AND FABRICATION TECHNIQUES REQUIRED WELDING AND FABRICATION TECHNIQUES	1	•	
TEMBILE REQUIREMENTS Ultimate RG/MR ² (RSI) Yield (ain.)RG/MR ² (RSI) Elongation (min.) t in 5.65)R NW (IN) or as noted (A-area of spe.) CHARPY V-NOTCH IMPACT TEST TEMPERATURE *C Energy, KG-M (FT-LB) MYZ TEMPERATURE *C DYNAMIC TEAR ENERGY IN RG-M (FT-LB) AT 24*C FOR 16 NW (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKILL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES REQUIRED WELDING AND FABRICATION TECHNIQUES	treated.	*If aluminum treated.	*Above 12.5 HM (1/2 TM),
TEMBLE REQUIREMENTS Ultimate RG/MR ² (RSI) Yield (min.)RG/MR ² (RSI) Elongation (min.) & in S.65)R MM (IN) or as noted (A=area of spe.) CHARPY V-MOTCH IMPACT TEST TEMPERATURE °C Energy, KG-M (FT-LB) MPT TEMPERATURE °C DYNAMIC TEAR ENERGY IN RG-M (FT-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKIL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES REQUIRED WELDING AND FABRICATION TECHNIQUES		**If columbium or vanadium	if nichium or aluminum
TEMBLE REQUIREMENTS Ultimate RG/MR ² (RSI) Yield (sin.)RC/MR ² (RSI) Slongation (sin.) & in 5.65)R MM (IN) or as noted (A-area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, RG-M (FT-LB) MOT TEMPERATURE °C JYMANIC TEAR BRENCY IN RG-M (FP-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN REQUIRED WELDING AND FABRICATION TECHNIQUES MOderate preivalding. Low FABRICATION TECHNIQUES		practice is used.	+ niobium prectice is used.
Ultimate RG/RM2 (RSI) Vield (ain.)RG/RM2 (RSI) Sield (ain.)RG/RM2 (Ain.) Sield (ain.)RG/RM2 (Ain.)RG/R		practice in them.	T INVESTMENT (A GEORGE CE CENTRE)
Ultimate RG/RM ² (RSI) Vield (min.)RG/RM ² (RSI) Elongation (min.) 4 in 5.65) R RM (IN) or as noted (A-area of spe.) CHARPY V-MOTCH IMPACT TEST Temperature °C Energy, RG-M (FT-LB) MIT TEMPERATURE °C DYMAMIC TEAR EMERGY IN RG-M (FT-LB) AT 24°C FOR 16 RM (5/B IN) THICK SPECIMEN ASPASSION RESISTANCE AS BRINELL MARCHESS REQUIRED WELDING AND PASSICATION TECHNIQUES Hoderate prei			
Ultimate RG/RM ² (RSI) Vield (min.)RG/RM ² (RSI) Elongation (min.) 4 in 5.65) R RM (IN) or as noted (A-area of spe.) CHARPY V-MOTCH IMPACT TEST Temperature °C Energy, RG-M (FT-LB) MIT TEMPERATURE °C DYMAMIC TEAR EMERGY IN RG-M (FT-LB) AT 24°C FOR 16 RM (5/B IN) THICK SPECIMEN ASPASSION RESISTANCE AS BRINELL MARCHESS REQUIRED WELDING AND PASSICATION TECHNIQUES Hoderate prei			
Ultimate RG/RM ² (RSI) Vield (min.)RG/RM ² (RSI) Elongation (min.) 4 in 5.65) R RM (IN) or as noted (A-area of spe.) CHARPY V-MOTCH IMPACT TEST Temperature °C Energy, RG-M (FT-LB) MIT TEMPERATURE °C DYMAMIC TEAR EMERGY IN RG-M (FT-LB) AT 24°C FOR 16 RM (5/B IN) THICK SPECIMEN ASPASSION RESISTANCE AS BRINELL MARCHESS REQUIRED WELDING AND PASSICATION TECHNIQUES Hoderate prei	J		
Ultimate RG/RM2 (RSI) Vield (ain.)RG/RM2 (RSI) Sield (ain.)RG/RM2 (Ain.) Sield (ain.)RG/RM2 (Ain.)RG/R			L
Ultimate RG/RM2 (RSI) Vield (sin.) RG/RM2 (RSI) Vield (sin.) RG/RM2 (RSI) S.65) R MM (IN) or as noted (A=area of spe.) CHARPY V-MOTCH IMPACT TEST Temperature °C Energy, RG-M (FT-LB) NPT TEMPERATURE °C DYMANIC TEAR BRENCY IN RG-M (FT-LB) AT 24°C POR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKLL HARDNESS REQUIRED WELDING AND PASSICATION TECHNIQUES PRECISE. N			
Tield (min.) NG/NM2 (NSI) Elongation (min.) a in 5.65 RM (IN) or as noted (A=area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, KG-M (FT-LB) 2.4 (17) Trai NNYT TEMPERATURE °C DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C FOR 16 NM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKILL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PACETICS.	1		J
Elongation (min.) % in 19 in 200 MM 5.65)R MM (IN) or as noted (Amerea of spe.) CHARPY V-NOTCH IMPACT TEST TEMPERATURE °C -24 (17) Trail MN/T TEMPERATURE °C -62 to DYNAMIC TEAR ENERGY IN RG-M (FF-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN AS BRINKILL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNOLOGISM MODERATION TECHNOLOGISM Potents prei wolding. Longative.	60 (68 - 85)	50 ~ 63 (71 ~ 90)	41 - 52 (50 - 74)
Elongation (min.) % in 19 in 200 MM 5.65)R MM (IN) or as noted (Amerea of spe.) CHARPY V-NOTCH IMPACT TEST TEMPERATURE °C -24 (17) Trail MN/T TEMPERATURE °C -62 to DYNAMIC TEAR ENERGY IN RG-M (FF-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN AS BRINKILL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNOLOGISM MODERATION TECHNOLOGISM Potents prei wolding. Longative.	2 (45.5)	36 (51)	27 (38.5)
CHARPY V-NOTCH IMPACT TEST TEMPERATURE °C Energy, EG-M (FT-LB) 2.4 (17) Trai MNT TEMPERATURE °C -62 to DYNAMIC TEAR ENERGY IN EG-M (FT-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKILL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PACTICE.	(8 IN) or 1	19 in 200 MM (8 IN) or	1 22
CHARPY V-NOTCH IMPACT TEST TEMPERATURE °C Energy, KG-M (FT-LB) NHYT TEMPERATURE °C DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKILL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PACTICE.	MM (2 (N)	22 in 50 MM (2 IN)	
CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, EG-M (FT-LB) MYT TEMPERATURE °C DYNAMIC TEAR EMERGY IN EG-M (FT-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKILL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES Practice. N		22 211 22 111 12 211	
TEST Temperature °C Energy, KG-M (PT-LB) 3.5 (25) Lond 2.4 (17) Trai MIT TEMPERATURE °C -62 to DYNAMIC TEAR EMERGY IN KG-M (PT-LB) AT 24°C POR 16 HM (570 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINELL MARDNESS 135 - REQUIRED WELDING AND PABRICATION TECHNIQUES Practice. N	· · · · · ·		
TEST Temperature °C Energy, KG-M (FT-LB) 3.5 (25) Lond 2.4 (17) Trai MIT TEMPERATURE °C DYNAMIC TEAR EMERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINELL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES Practice. N			
TEST Temperature °C Energy, KG-M (PT-LB) 3.5 (25) Lond 2.4 (17) Trai MyT TEMPERATURE °C -62 to DYNAMIC TEAR EMERGY IN RG-M (PT-LB) AT 24°C POR 16 HM (570 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINELL MARDNESS 135 - REQUIRED WELDING AND PABRICATION TECHNIQUES Practice. N	1		
Temperature °C			
Energy, RG-M (FT-LS) 3.5 (25) Lone 2.4 (17) Tree MAT TEMPERATURE *C DYNAMIC TEAR ENERGY IN RG-M (FT-LB) AT 24*C FOR 16 MM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKIL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PROTECTION TECHNIQUES PROTECTION TECHNIQUES	J		
2.4 (17) Trai MYT TEMPERATURE *C -62 to DYNAMIC TEAR EMERGY IN RG-M (PT-LB) AT 24*C FOR 16 MM (5/B IN) THICK SPECIMEN ADRASION RESISTANCE AS BRINKILL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES Practice. N		-20	-20
NOT TEMPERATURE °C -62 to DYNAMIC TEAR EMERGY IN RG-M (PT-LB) AT 24°C POR 16 MM (5/8 IM) THICK SPECIMEN ABRASION RESISTANCE AS BRINELL MARDNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PRACTICE. N		3.5 (25) Longitudinel	2.75 (20) Longitudinal
DYNAMIC TEAR ENERGY IN RG-M (PT-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKILL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES Practice. N	8V0780	2.4 (17) Transverse	
DYNAMIC TEAR ENERGY IN RG-M (PT-LB) AT 24°C FOR 16 MM (5/B IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKILL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES Practice. N			
IN RG-M (PT-LB) AT 24°C POR 16 MM (5/D IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKIL MARCHESS 135 - REQUIRED MELDING AND PABRICATION TECHNIQUES Practice. N	-40 [-62 to -40	
IN RG-M (PT-LB) AT 24°C POR 16 MM (5/D IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKIL MARCHESS 135 - REQUIRED MELDING AND PABRICATION TECHNIQUES Practice. N			
FOR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINKILL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES practice. N			
ABRASION RESISTANCE AS BRINKILL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PRECISE. N			
THICK SPECIMEN ASPASION RESISTANCE AS BRINKLL MARKNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PRECISE. N	i		
ABRASION RESISTANCE AS BRINKIL MARCHESS 135 - Moderate pre- MEQUIRED MELDING AND FABRICATION TECHNIQUES practice. In	i		
BRINELL MARGNESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES practice. No	Į		
BRINELL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PARTICATION TECHNIQUES PROBLEM			
BRINELL MARCHESS 135 - REQUIRED WELDING AND FABRICATION TECHNIQUES PARTICATION TECHNIQUES PROBLEM	1		
ASCHIRED WELDING AND Welding. Low FABRICATION TECHNIQUES practice. No	!	***	
REQUIRED WELDING AND welding. In FABRICATION TECHNIQUES practice. No	1/0	140 - 161	110 - 147
REQUIRED WELDING AND welding. In FABRICATION TECHNIQUES practice. No			
REQUIRED WELDING AND PARTICIPATION TECHNIQUES Fractice. No cutting pro-	eat for	Moderate preheat for	Moderate preheat for
FASRICATION TECHNIQUES practice. No 6 cutting pro	-hydroyen	welding. Low-hydrogen	welding. Low-hydrogen
6 cutting pro	rmal forming	practice. Normal forming	practice. Mormal forming
,	ctice.	6 cutting practice.	& cutting practice.
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l l	l		l
			_,
APIATIUS CIUT VACTOR	l		4.70
(Besed on ABS Grade A)	1	1. 16	7. 18
Emases on ARS Grade Al	j.		1
RELATIVE CUST PACTOR 1.3		5 dutting practice.	1.1R

TABLE 8-3.3 (Continued)

STREL TYPE 6 GRADE	Lloyd's Register NTS Gr. DH32	Lloyd's Register NTS Gr. DN348	Lloyd's Register HT6 Gr. DH36
	Open-hearth, electric-	Open-hearth, electric-	Open-hearth, electric-
PROCESS OF MANUFACTURE	furnace, or heatc-maygen process	furnace, or basic-oxygen process	furnace, or hasic-oxygen process
DECKIDATION	Semi-killed or silicon- killed	Semi-killed or silicon- killed	Semi-killed or silicon- killed
HEAT TREATMENT	Mormd.above 25.5 MM (1 IN)	Normd.above 25.5 MM (1 IN)	Normd.above 25.5 HM (1 18)
CHEMICAL COMPOSITION (Ladie Analysis - %)			
Carbon (max.) Manganese Phoaphorus (max.) Sulphur (max.)	0.18 0.90 - 1.60 0.04 0.04	0.18 0.90 - 1.60 0.04 0.04	0.16 0.90 - 1.60 0.04 0.04
Silicon	0.05 max.	0.05 max.	0.05 max.
Chromium	0.20 max.	0.20 max.	0.20 max.
Nickel	0.40 max.	0.40 max.	0.40 max.
Mr I ybdenum	0.00 max.	0.08 max.	O.OR max.
Copper	0.35 max.	0.35 max.	0.35 max.
Titanium			ł
Vanadium	0.03 - 0.10	0.03 - 0.10	H.03 - 0.10
A2 um i num	0.015 min.	0.015 min.	0.015 min.
Others	0.015 - 0.05 Mb	0.015 - 0.05 Nb	0.015 - 0.05 Nb
Motes:	*Above 12.5 MM (1/2 IN), if niobium or aluminum + niobium practice in used.	*Above 12.5 MM (1/2 IN), if niobium or aluminum + niobium practice is used.	*Ahove 12:5 RM (1/2 IN), if niobium or aluminum + niobium practice is used.
TEMBILE REQUIREMENTS Ultimate KG/Mm² (KSI) Yield (min.) KG/Mm² (KSI) Elongation (min.) % in 5.65 jā Mm (IM) or as noted (A-area of spe.)	45 - 60 (64 - 85) 32 (45.5) 22	62 (86) 34 (48) 22	50 - 63 (71 - 90) 36 (51) 21
CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, KG-M (FT-LB)	-20 3.16 (23) Longitudinal	-20 3.47 (25) Longitudinal	-20 3.47 (25) Longitudinal
NOT TEMPERATURE *C		<u></u>	
DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN	•		
ABRASION RESISTANCE AS DRINELL HARDNESS	125 - 170	177	140 - 181
REQUIRED MELDING AND FABRICATION TECHNIQUES	Moderate preheat for welding. Low-hydrogen practice. Mormal forming 6 cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Mormal forming & cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Normal forming & cutting practice.
PELATIVE COST FACTOR Chases on ARS Grade A)	1.36	1,36	1.30

TABLE B-3.3 (Continued)

STEEL TYPE & GRADE			
STEEL TIPE & GRADE	Horake Veritas	Horake Veritas	Horske Veritas
	NTS Gr. HVD278	NTS Gr. NVD32 Open-hearth, hesic-oxygen,	NTS Gr. NVD36 Open-hearth, hasic-oxygen,
PROCESS OF HAMUFACTURE	or electric-furnece process		or electric-furnace process
The state of the s	or creative randor process	process	or electric-rurnace process
DEOX1DATION	Semi-killed or fully	Fully killed	Pully killed
HEAT TREATMENT	311)ed*		
HEAT THEATHERT	Hotad.spore 52:2 MM(1 IM)**	Morad.above 19 MM(3/4 IN)*	Moradiabove 19 MM(3/4 IN)*
CHEMICAL CUMPOSITION			
(Ladle Analysis - %)			
• • • • • • • • • • • • • • • • • • • •			
	i		
Carbon (max.)	0.18	0.10	0.18
Manganese	0.70 min.	0.9 - 1.6	0.9 - 1.6
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (mex.)	0.04	0.04	0.04
Silicon	I	0.10 - 0.50	0.10 - 0.50
Chromium	0.20 max.	0.20 max.	0.20 max.
Hickel	0.40 max.	0.40 max.	0.40 max.
No.1 ybdenum	0.00 max.	0.08 max.	0.08 max.
Copper Titanium	0.35 max.	0.35 max.	0.35 max.
Titanium Vanadium	0.10 max.	0.10 max.	0.10 max.
Aluminum	0.00 max.	0.00 max.	0.00 max.
Others	9.05 max. No	0.05 max. 16	0.05 max. 165
]		•
Notes:	*Por 25.5 NM (1 IN) and	*Above 12.5 MM (1/2 IN),	*Above 12.5 MM (1/2 IN),
	shove to he killed and	if niobium practice is	if niobium practice is
	fine grain treated.	used.	used.
	**Above 12.5 MM (1/2 IM), if mioblum practice is		
	used.		
	, use		
TENSILE REQUIREMENTS			
Ultimate SG/ISI ² (KSI)	41 - 52 (58 - 74)	45 - 60 (64 - 85)	50 - 63 (71 - 90)
Yield (min.) KG/MH ² (KS1) Elongation (min.) % in	27 (30.5) 22	32 (45.5)	36 (51)
5.65 1A MM (IN) or as		22	21
noted (A=area of spe.)			
CHARPY V-HOTCH IMPACT			
TEST	-20	-20	
Temperature °C Energy, RG-M (FT-LB)	-20 2.75 (20) Longitudinal	-20 3.16 (23) Longitudinal	-20 3.47 (25) Longitudinal
Energy, KG-M (FI-LB)	2.75 (20) Longitudinal 2.0 (14) Transverse	2.24 (16) Transverse	2.45 (10) Transverse
	/ :- stangarding	0.04 .A:	21-27 7 : AL 11 AUBART 86
HOT TEMPERATURE *C			
DYNAMIC TEAR BIERGY			
IN NG-H (PT-LB) AT 24°C			
POR 16 MM (5/8 IN) TRICK SPECIMEN			
THICK SPECIMEN			
			
AGRASION RESISTANCE AS	110 - 147	125 - 170	140 - 181
ORINGLL HARINGSS		· · · · · · · · · · · · · · · · · · ·	·
			L
	Hoderate preheat for	Moderate preheat for	Moderate preheat for
PROFITED WELDING AND	welding. fow-hydrogen practice. Mormal forming	welding. Low-hydrogen	welding. Low-hydrogen practice. Mormal forming
FASRICATION TECHNIQUES	practice. Mormal forming a cutting practice.	practice. Mormal forming & cutting practice.	practice. Mormal forming & cutting practice.
	a cutting prectice.	e cutting practice.	a cutting practice.
PELATIVE COST PACTOR	1.30	1.38	1.16
(Beset in ABS Grade A)			I
	l		\

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	Horske Veritas	Nureau Veritas	Bureau Veritas
	MTS Gr. WVD40S Open-hearth, basic-oxygen,	MTS Gr. 0032 Open-hearth, basic-oxygen,	NTS Gr. DH36 Open-hearth, hasic-oxygen,
PROCESS OF MANUFACTURE	or electric-furnace process		electric-furnace, or any
	•	equivalent approved by	equivalent approved by
		the society	the society
DECKIDATION	Fully killed	Rilled, fine grain	Killed, fine grain
HEAT TREATMENT	Normalized	Mormalized*	Normalizada
CHEMICAL COMPOSITION			ĺ
(Ladle Analysis - %)			į.
Carbon (max.)	0.18	0.18	0.18
Manganese	0.9 - 1.6	0.90 - 1.60	0.90 - 1.60
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.) Silicon	0.04 0.10 - 0.50	0.04 0.10 - 0.50	0.04 0.10 - 0.50
Silicon Chromium	0.10 - 0.50 0.20 max.	0.10 - 0.50 0.20 max.	0.10 ~ 0.50
Nickel	0.40 max.	0.20 mex. 0.40 mex.	0.40 max.
Mo1 ybdenum	0.08 max.	0.08 max.	0.08 max.
Copper	0.35 max.	0.35 max.	0.35 max.
Titanium	_	_	
Vanadium Aluminum	0.10 max.	0.10 max.	0.05 - 0.10
Aluminum Others	0.08 max. 0.05 max. Mb	0.015 - 0.06 0.05 max. Mh	0.015 - 0.06 0.02 - 0.05 NB
(Rifers	U.95 Max. ND	U.US Max. Wh	0.02 - 0.05 Nm
Motes:		*Not required, if properties can be met as specified.	*Not required, if properties can be set as specified.
TEMBILE REQUIREMENTS Ultimate NG/NM ² (KSI) Yield (min.)NG/NM ² (KSI) S.65 jA NM (IN) or as noted (A-area of spe.)	54 - 6h (77 - 94) 40 (57) 20	45 - 50 (64 - 85) 32 (45.5) 20	50 - 63 (71 - 90) 36 (51) 20
CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, KG-M (FT-LB)	-20 4.0 (29) Longitudinal 2.65 (19) Transverse	-20 3.16 (23) Longitudinal	-20 3.5 (25) Longitudinal
NOT TEMPERATURE *C			
DYNAMIC TEAR ENERGY IN MG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN			
ABRASION RESISTANCE AS BRINELL HARIMESS	153 - 190	125 - 170	140 - 161
REGITERD WELDING AND PARRICATION TECHNIQUES	Moderate preheat for welding. Lim-hydrogen practice. Mormal forming & cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Normal forming 6 cutting practice.	Noderate preheat for welding. Low-hydrogen practice. Mormal forming 6 cutting practice.
RELATIVE COST FACTOR (Base Foo ABS Grade A)	1.38	1.38	1.38

TABLE B-3.3 (Continued)

STEEL TYPE & GRADE	HKK	HKK	German. Lloyd
	HTS Gr. KD32	HTS Gr. KD36	HTS Gr. D32
PROCESS OF MANUFACTURE	Open-hearth, basic-oxygen, electric-furnace	Open-hearth, hemic-oxygen,	Open-hearth, hasic-oxygen
PRICESS OF HARDFACTURE	process, or other approved	electric-furnace process, or other approved	electric-furnace process,
	by the society	by the society	or other approved by the society
DECKIDATION	Killed	Killed	Filled
HEAT TREATMENT	Normalized	Normalized	Normalized
		1071-1111	HOT WELLERS
CHEMICAL COMPOSITION (Ladle Analysis - %)			
That e Histysis - wy			
Carbon (mex.)	0.18	0.18	0.18
Manyanese	0.90 - 1.60	0.90 - 1.60	0.90 - 1,60
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.)	0.04	0.04	0.04
Silicon Chromium	0.10 ~ 0.50	0.10 + 0.50	0.10 - 0.50
Chromaum Nickel	0.20 max.	0.20 max.	0.20 max.
Nicke) Wilybrienum	0.40 max.	0.40 max.	0.40 max.
	0.08 max.	0.08 max.	O.OR max.
Copper Titanium	0.35 max.	0.35 max.	0.35 max.
Titanium Vanadium		l	l
Venacium Aluminum	0.015 min.	0.05 - 0.10 0.015 min.	0.02 - 0.07
Others	0.075 min.	0.02 ~ 0.05 Mb	
OCHET#		0.02 ~ 0.05 Nm	1
Mosters:			
TENSILE REQUIREMENTS Ultimate RC/NM ² (RSI) Yield (min.)RC/NM ² (RSI) Slongation (min.) % in 5.65 jK NM (IN) or as noted (Amarea of spe.)	48 - 50 (68 - 85) 32 (45.5) 22	50 - 63 (71 - 90) 36 (51) 21	4R - 60 (6R - 85) 32 (45.5) 22
CHARPY V-NOTCH IMPACT FEST Temperature *C Inergy, KG-M (FT-LB)	-20 3.2 (23) Longitudinal 2.3 (17) Transverse	-20 J.5 (25) Longitudinal 2.5 (18) Transverse	-20 3.2 (23) Longitudinel 2.2 (16) Transverse
NOT TEMPERATURE *C			
DYNAMIC TEAR EMERGY IN RI-M (PT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN			
ABRASION RESISTANCE AS BRINKLL HARINESS	135 - 170	140 - 181	135 - 170
REQUINED WELDING AND PARRICATION TECHNIQUES	Moderate preheat for welding. Low-hydrogen practice. Moreal forming a cutting practice.	Noderate preheat for welding, Low-hydrogen practice. Mormal forming 6 cutting practice.	Moderate prohest for welding. Inw-hydrogen practice. Normal forming & cutting practice.
PRIATIVE COST FACTOR CHARGE OF ABS GLADE AS	1. 14	1.38	1.38

TABLE B-3.3 (Continued)

STEEL TYPE 6 GRADE	German. Lloyd	ASTN-A5)7	ASTM-A633
SIEEE IIFE & GROUP	HTS GR. D36	Class 1	Gr. D
	Open-hearth, basic-oxygen,	Open-hearth, basic-oxygen,	Open-hearth, hesic-oxygen,
PROCESS OF MAMUFACTURE	electric-furnace, or any	or electric-furnace	or electric-furnace
	equivalent approved by the	process	process
DECKIDATION	society Killed	Fine grain practice	Fine grain practice
DECKLIMITION	KIII 64	Live drawn bractice	Alue destu braccica
HEAT TREATMENT	Hormalized	Normalised	Normalized
CHEMICAL COMPOSITION (Ladic Analysis - %)		1	
(Ladie shallAsis - #)			
			1
Carbon (max.) Manganese	0.18 0.90 - 1.60	0.24 0.70 - 1.35	0.20 0.70 - 1.35
Phosphorus (max.)	0.90 - 1.60	0.70 - 1.35	0.70 - 1.35
Sulphur (max.)	0.04	0.040	0.05
Silicon	0.10 - 0.50	0.15 - 0.50	0.15 - 0.50
Chromium	0.20 max.	0.25 max.	0.25 mass.
Nickel	0.40 max.	0.25 max.	0.25 max.
Mo1 ybdenim	0.08 max.	0.08 max.	0.08 max.
Copper	0.35 max.	0.35 max.	0.35 max.
Titenium		l	
Vanadium Aluminum	0.05 - 0.10 0.02 - 0.07	1	ì
Aluminum Others	0.02 - 0.07 0.02 - 0.05 NB	1	ļ
Cher 2	1		1
Notes:		i	İ
		ŀ	
			1
			1
			Į
			
TENSILE REQUIREMENTS		ł	1
Ultimate KG/HH ² (KS1)	50 - 63 (71 - 90)	49 - 63 (70 - 90)	49 - 63 (70 - 90)
Yield (min.) KG/HH2 (KS1)		35 (50)	35 (50)
Elongation (min.) % in	21	22	23
5.65 A MM (IN) or as noted (A-area of spe.)		in 51 MM (2 IN)	in 51 MM (2 IN)
noted (A-area of spe.)			
CHARPY V-NOTCH IMPACT		ì]
TEST			}
Temperature °C	-20	-60	-40
Energy, KG-M (FT-LB)	3.5 (25) Longitudinal 2.4 (17) Transverse	2.1 (15) Longitudinal	3.5 (25) Longitudina
	2.4 (1/) Itamaverse		2.8 (20) Transverse
NIST TEMPERATURE *C		-51 to -18	-51 aver.
			l
DYNAMIC TEAR ENERGY			
IN WI-M (FT-LB) AT 24°C			[
POR 16 MM (5/8 IN) THICK SPECIMEN		Ī	I
		J	1
0.00		ľ	1
ANRASION RESISTANCE AS	140 - 161	138 - 161	136 - 181
	140 - 191	138 - 161	138 - 181
ANRASION RESISTANCE AS			
ARRASIUM MESISTANCE AS BRINKLL, HARINKSS	Movierate preheat for	Controlled welding	Controlled welding
ARPASION RESISTANCE AS BRINELL HARTMESS	Moderate preheat for welding. Low-hydrogen	Controlled welding	Controlled welding process. Moderate
ARRASIUM MESISTANCE AS BRINKLL, HARINKSS	Movierate preheat for	Controlled welding	Controlled welding process. Moderate
ARPASION RESISTANCE AS BRINELL HARTMESS	Moderate preheat for welding. Low-hydrogen practice. Normal forming		Controlled welding
ARPASION RESISTANCE AS BRINELL HARTMESS	Moderate preheat for welding. Low-hydrogen practice. Normal forming	Controlled welding process. Moderate preheat. Low-hydrogen practice. Mormal forming	Controlled welding process. Moderate preheat. Low-hydrogen practice. Mormal forming
ARRASION RESISTANCE AS BRINKLL MARDNESS REGISHED MELDING AND PARKICATION TECHNIQUES	Moderate preheat for welding. Low-hydrogen practice. Normal forming and cutting practice.	Controlled welding process. Moderate preheat. Low-hydrogen practice. Normal forming a cutting practice.	Controlled uniding process. Moderate preheat. Low-hydrogen practice. Normal forming & cutting practice.
ARPASION RESISTANCE AS BRINELL HARTMESS	Moderate preheat for welding. Low-hydrogen practice. Normal forming	Controlled welding process. Moderate preheat. Low-hydrogen practice. Mormal forming	Controlled welding process. Moderate preheat. Low-hydrogen practice. Mormal forming

TABLE - B-3.3 (Continued)

STEEL TYPE & GRADE	ASTM-A633	ADS	ABS
	Gr. A 6 B	NTS Gr. EN32	HTS Gr. CH36
	Open-hearth, basic-oxygen,	Open-hearth, basic-oxygen,	Open-hearth, basic-oxygen
PROCESS OF MANUFACTURE	or electric-furnace	or electric-furnace	or electric-furnace
	process	process	process
DECKIDATION	Pine grain practice	Killed, fine grain practice	Killed, fine grain practi
HEAT TREATMENT	Hormalised	Normalised	Normalised
CHEMICAL COMPOSITION	1	1	
(Ladle Analysis - %)			
		!	
Carbon (max.)	0.18	0.18	0.18
Manganess Phosphorus (max.)	1.00 ~ 1.35 0.04	0.90 - 1.50	0.90 - 1.60
Sulphur (max.)		0.04	0.04
Silicon	0.05	0.04	0.04
Silicon Chromium	0.15 - 0.50	0.10 - 0.50 0.25 max.	0.10 - 0.50 0.25 max.
Unramium Nickel	ĺ	0.25 max. 0.40 max.	0.25 max. 0.40 max.
Mickel Milybdenum	í	0.40 max. 0.08 max.	
Copper	1	0.00 man. 0.35 max.	0.08 max. 0.35 max.
Copper Titanium		U. JO MAK.	บ.35 สสมเ
Vanadium	0.10 max.*	0.10 max.	0.10 max.
Aluminum	J		U. 10 Max.
Others	0.05 max. Cb**	0.05 max. Ch	0.05 max. Cb
]	0103 man. Car	U.U3 Metr. CD
Notes:	*Gr. B only.	į	
	**Gr. A only.	l ·	
TENSILE REQUIREMENTS		i	
Ultimate RG/MM ² (ESI)	44 - 58 (63 - 83)	48 - 60 (68 - 85)	50 - 63 (71 - 90)
Ultimate RG/MM ² (RSI) Yield (min.)RG/MM ² (RSI)	30 (43)	32 (45.5)	36 (51)
Ultimate RG/MM ² (RSI) Yield (min.) RG/MM ² (RSI) Elongation (min.) % in	30 (43) 23	32 (45.5) 19 in 200 MM (8 IN) or	36 (51) 19 in 200 NM (8 IN) or
Ultimate RG/MM ² (RSI) Yield (min.)RG/MM ² (RSI) Elongation (min.) % in 5.65 (A MM (IN) or as	30 (43)	32 (45.5)	36 (51)
Ultimate RG/MM ² (RSI) Yield (min.) RG/MM ² (RSI) Elongation (min.) % in	30 (43) 23	32 (45.5) 19 in 200 MM (8 IN) or	36 (51) 19 in 200 NM (8 IN) or
Ultimate RG/MM ² (RSI) Yield (min.)RG/MM ² (RSI) Elongation (min.) % in 5.65) R MM (IN) or as noted (A=area of spe.)	30 (43) 23	32 (45.5) 19 in 200 MM (8 IN) or	36 (51) 19 in 200 MM (# IN) or
Ultimate NG/MM ² (RSI) Yield (min.iNG/MM ² (RSI) Elonqation (min.) & in 5.65 j R MM (IN) or as noted (A-area of spe.) CHARPY V-NOTCH IMPACT TEST	30 (43) 23 in 51 MM (2 IN)	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM)	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IN)
Ultimate RG/MM ² (RSI) Yield (min.)RG/MM ² (RSI) Elongation (min.) % in 5.65 j R MM (IN) or as noted (A=area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature *C	30 (43) 23 in 51 MM (2 IN) -46	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM)	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IN)
Ultimate NG/MM ² (RSI) Yield (min.)NG/MM ² (RSI) Blongation (min.) & in 5.65 j km (IN) or as noted (A=area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature *C	30 (43) 23 in 51 MM (2 IN) -46 3-5 (25) Longitudinal	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3-5 (25) Longitudinal	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IN) -40 3-5 (25) Longitudina
Ultimate NG/MM ² (RSI) Yield (min.)NG/MM ² (RSI) Siongation (min.) % in 5.65 j km (IN) or as noted (A=area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, KG-M (FT-LB)	30 (43) 23 in 51 MM (2 IN) -46	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM)	36 (51) 19 in 200 MM (# IN) or 22 in 50 MM (2 IM)
Ultimate NG/MM ² (RSI) Yield (min.) NG/MM ² (RSI) Elongation (min.) & in 5.65 j\(\bar{R}\) MM (IN) or as noted (A=area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, KG-M (FT-LB) NUT TEMPERATURE *C	30 (43) 23 in 51 MM (2 IN) -46 3-5 (25) Longitudinal	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3-5 (25) Longitudinal	36 (51) 19 in 200 MM (# IN) or 22 in 50 MM (2 IN) -40 3-5 (25) Longitudina
Ultimate RG/MM ² (RSI) Yield (min.)RG/MM ² (RSI) Siongation (min.) & in Sio5 y	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudinal 2.4 (17) Transverse	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IM) -40 3-5 (25) Longitudina 2-4 (17) Transverse
Ultimate NG/MM ² (RSI) Yield (min.)NC/MM ² (RSI) Elongation (min.) & in 5.65) The (IN) or as noted (A=area of spe.) CHARPY V-HOTCH IMPACT TEST Temperature °C Energy, KG-M (FT-LB) HOT TEMPERATURE °C DYNAMIC TEAR ENERGY IN NG-M (FT-LB) AT 24°C	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IM) -40 3-5 (25) Longitudina 2-4 (17) Transverse
Ultimate RG/MM ² (RSI) Yield (min.)RC/MM ² (RSI) Elongation (min.) & in 5.65 j R MM (IN) or as noted (A=area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, RG-M (FT-LB) NOT TEMPERATURE *C DYNAMIC TEAR EMERGY FOR 16 FM (5/8 IN)	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudinal 2.4 (17) Transverse	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IM) -40 3-5 (25) Longitudina 2-4 (17) Transverse
Ultimate RG/MM ² (RSI) Yield (min.)RC/MM ² (RSI) Filongation (min.) & in 5.65 j mm (IN) or as noted (A=area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, RG-M (FT-LB) NUT TEMPERATURE *C DYNAMIC TEAR EMERGY IN RG-M (FT-LB) AT 24*C FOR 16 MM (5/8 IN) THICK SPECIMEN	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse -57 aver.	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40 91 (658)	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IN) -40 3-5 (25) Longitudina 2-4 (17) Transverse -51 to -40
Ultimate RG/MM ² (RSI) Yield (min.)RG/MM ² (RSI) Siongation (min.) & in S.65) The (IN) or as noted (A=area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, RG-M (FT-LB) NUT TEMPERATURE *C DYNAMIC TEAR EMERGY IN RG-M (FT-LB) AT 24*C FOR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IN) -40 3-5 (25) Longitudina 2-4 (17) Transverse
Ultimate NG/NH ² (RSI) Yield (sin.1NC/NH ² (RSI) Elongation (min.) & in 5.65) The (IN) or as noted (A-area of spe.) CHARPY V-NOTCH IMPACT TEST Temperature "C Energy, NG-M (FT-LB) NOT TEMPERATURE "C DYNAMIC TEAR ENERGY IN NG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINELL MARDNESS	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse -57 aver. 121 - 165 Preheat required, if	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IN) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40 91 (658) 135 - 170 Moderate preheat for	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IN) -40 3.5 (25) Longitudina 2.4 (17) Transverse -51 to -40 140 - 181
Ultimate RG/MM ² (RSI) Yield (sin.1RC/MM ² (RSI) Yield (sin.1RC/MM ² (RSI) S.65.) The (IN) or se noted (A=stea of spe.) CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, KG-M (FT-LB) NDT TEMPERATURE *C DYNAMIC TEAR EMERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINELL MARDNESS PEQUIRED WELDING AND	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse -57 aver. 121 - 165 Preheat required, if ambient temp, below 16°C,	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IN) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40 91 (658) 135 - 170 Moderate preheat for	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IN) -40 3.5 (25) Longitudina 2.4 (17) Transverse -51 to -40 140 - 181
Ultimate RG/MM ² (RSI) Yield (sin.)RC/MM ² (RSI) Elongation (sin.) % in 5.65 (% MM (IN) or as noted (A=stea of spe.) CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, RG-M (FT-LB) NUT TEMPERATURE °C DYNAMIC TEAR ENERGY IN RG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINGLL MARDNESS	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse -57 aver. 121 - 165 Preheat required, if ambient temp, below 16°C. Low-hydrogen practice.	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40 91 (658) 135 - 170 Moderate preheat for welding. Low-hydrogen practice. Normal forming	36 (51) 19 in 200 MM (0 IN) or 22 in 50 MM (2 IN) -40 3.5 (25) Longitudina 2.4 (17) Transverse -51 to -40 Moderate preheat for welding, Low-hydrogen practice, Normal forming
Ultimate NG/NH2 (RSI) Yield (sin. NC/NH2 (RSI) Filongation (sin.) & in 5.65) N MM (IN) or se noted (A=srea of spe.) CHARPY V-NOTCH IMPACT TEST Temperature "C Energy, KG-M (FT-LB) NUT TEMPERATURE "C DYNAMIC TEAR EMERGY IN KG-M (FF-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINELL MARDNERS PEQUIRED MELDING AND	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse -57 aver. 121 - 165 Preheat required, if ambient temp, below 16°C,	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IN) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40 91 (658) 135 - 170 Moderate preheat for	36 (51) 19 in 200 MM (8 IN) or 22 in 50 MM (2 IN) -40 3.5 (25) Longitudina 2.4 (17) Transverse -51 to -40 140 - 181
Ultimate RG/MM ² (RSI) Yield (sin.1RC/MM ² (RSI) Filongation (sin.) & in 5.65) The (IN) or as noted (A-area of spe.) CHARPY V-HOTCH IMPACT TEST Temperature °C Energy, KG-M (FT-LB) HOT TEMPERATURE °C DYNAMIC TEAR ENERGY IN RG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINGLI, HARDHERS REQUIRED MELDING AND FARRICATION TECHNIQUES	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse -57 sver. 121 - 165 Preheat required, if ambient temp, below 16°C, Low-hydrogen practice. Normal forming & cutting practice	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40 91 (658) 135 - 170 Hoderate preheat for welding. Low-hydrowen practice. Normal forming 6 cutting practice.	-40 3.5 (25) Longitudina 2.4 (17) Transverse -51 to -40 Moderate preheat for welding. Low-hydrogen practice. Normal forming 6 cutting practice.
Ultimate NG/NH2 (RSI) Yield (min.) NC/NH2 (RSI) Elongation (min.) & in 5.65) N MM (IN) or me noted (A=mrem of spe.) CHARPY V-NOTCH IMPACT TEST Temperature "C Energy, KG-M (FT-LB) NUT TEMPERATURE "C DYNAMIC TEAR ENERGY IN NG-M (FF-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN ABRASION RESISTANCE AS BRINELL MARDNESS PEQUIRED MELDING AND	30 (43) 23 in 51 MM (2 IN) -46 3.5 (25) Longitudinal 2.8 (20) Transverse -57 aver. 121 - 165 Preheat required, if amhlent temp, below 16°C. Low-hydrogen practice. Mormal forming & cutting	32 (45.5) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudinal 2.4 (17) Transverse -51 to -40 91 (658) 135 - 170 Moderate preheat for welding. Low-hydrogen practice. Normal forming	36 (51) 19 in 200 MM (8 IM) or 22 in 50 MM (2 IM) -40 3.5 (25) Longitudina 2.4 (17) Transverse -51 to -40 Moderate preheat for welding, Low-hydrogen practice. Normal forming

TABLE 8-3.3 (Continued)

PROPERTIES OF STEELS USED FOR ICE-STRENGTHENED SHIPS

STEEL TYPE & GRADE	Lloyd's Register NTS Gr. EH275	Lloyd's Register HTS Gr. BH32	Lloyd's Register HTS Gr. EH34S
	Open-hearth, hasic-oxygen,	Open-hearth, hasic-oxygen,	Open-hearth, hasic-oxygen
PROCESS OF MARRIPACTURE	or electric-furnace	or electric-furnace	or electric-furnace
	process	process	process
DECKIDATION	Silicon-killed only	Silicon-killed only	Silicon-killed only
HEAT TREATMENT	Mormalized	Normalized	Normalized
CHEMICAL COMPOSITION (Ladle Analysis - %)			
Carbon (max.)	0.18 0.70 - 1.60	0.18	0.18
Manganese	0.70 - 1.60	0.90 - 1.60	0.90 - 1.60
Phosphorus (max.)	0.04	0.04	0.04
Sulphui (max.) Silicon	0.04 0.10 min.	0.04	0.04
Chromium	0.70 min.	0.10 min. 0.20 max.	0.10 min.
Chromium Nickel	0.40 max.	0.20 max. 0.40 max.	0.20 max. 0.40 max.
Molyhdenum Molyhdenum	0.40 max.	0.40 max. 0.08 max.	0.40 max. 0.00 max.
но гупаетия Соррег	0.35 wax.	0.70 max. 0.35 max.	0.00 max. 0.35 max.
Copper Titanium	V-37 WAX.	U. Jo Max.	U.35 Max.
Vanedium	0.03 - 0.10	0.03 - 0.10	0.03 - 0.10
Aliminum	0.015 min.	0.015 min.	0.015 min.
(Rhers	0.015 - 0.05 Nb	9.015 - 0.05 NB	0.015 - 0.05
	1	1 31013 - 3103 12.	J,
Notes:			
TENSILE REQUIREMENTS Ultimate KG/MM ² (KSI) Vield (min.)KG/MM ² (KSI) Elongation (min.) % in 5.65 ¼ MM (IN) or as noted (A=area of spe.)	41 - 52 (58 - 74) 27 (38,5) 22	45 - 60 (64 - 85) 32 (45.5) 22	62 (90) 34 (40) 22
CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, KG-M (FT-LB)	-40 2.75 (20) Longitudinal	-40 3.16 (23) Longitudinal	-40 3.47 (25) Longitudin
NOT TEMPERATURE *C			
DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C POR 16 MM (5/8 IN) THICK SPECIMEN			
ABRASION RESISTANCE AS BRINELL HARINESS	110 - 147	125 - 170	177
REQUIRED WELDING AND PABRICATION TECHNIQUES	Hoderate preheat for welding. Low-hydrogen practice. Hormal forming a cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Hormal forming 6 cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Normal forming & cutting practice.
RELATIVE COST FACTOR (Based on ABS Grade A)	1.41	1.41	1,41

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	Lloyd's Register	Norske Verites	Norske Veritas
	NTS Gr. EH36	HTS Gr. HVE278	HTS Gr. NVE32
PROCESS OF MANUFACTURE	Open-hearth, hasic-oxygen, or electric-furnace	Open-hearth, hasic-oxygen, or electric-furnace	Open-hearth, hesic-oxygen
PROCESS OF IMMOTRICIONS	process	brocesss or electric-intusce	or electric-furnace process
DEOXIDATION	Silicon-killed only	Fully killed	Fully killed
HEAT TREATMENT	Mormalized	Normalized	Normalized
CHEMICAL COMPOSITION			
(Ladle Analysis - %)		l	
(and)			
Carbon (max.)	0.18	0.18	0. te
Mangenese	0.30 - 1.60	0.70 min.	0.9 - 1.6
Phosphorus (max.)	0.04	0.04	9.04
Sulphur (max.)	0.04	0.04	0.04
Silicon Chromium	0.10 min. 0.20 max.	0.10 - 0.50	0.10 - 0.50
Chromium Nickel	0.20 max. 0.40 max.	0.20 max.	0.20 max.
Ny lybdenum	0.40 max. 0.00 max.	0.40 max. 0.00 max.	0.40 max. 0.08 max.
Copper	0.35 max.	0.35 max.	0.00 max. 0.35 max.
Titanium	V MEA.	0.33 MEX.	U.JT MAX.
Venedium	0.03 - 0.10	0.10 max.	0.10 max.
Altminum	0.015 min.	0.38 max.	0.00 max.
Chers	0.01 - 0.05 Nb	0.05 max. Nb	G.05 max. No
Notes:		l	
TEMSILE REQUIREMENTS Ultimate NG/MP ² (NSI) Vield (en.) NG/MP ² (KSI) Elongation (min.) % in 5.65 N MM (IN) or as noted (A-area of spe.)	50 - 63 (71 - 90) 36 (51) 21	41 - 54 (58 - 77) 27 (38-5) 22	45 - 60 (64 - 85) 32 (45-5) 22
CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, KG-M (PT-L8)	-40 3-47 (25) Longitudinal	-40 2.75 (20) Longitudinel 2.0 (14) Transverse	-40 3.16 (23) Longitudine 2.24 (16) Transverse
NUT TEMPERATURE *C		2.00 3.77 2.000 2.010	2.124 (10) 2.131041.00
DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN			
ABRASI'M RESISTANCE AS BRINELL HARDNESS	140 - 181	110 - 153	125 - 170
REQUIRED WELDING AND FABRICATION TECHNIQUES	Moderate preheat for welding. Low-hydrogen practice. Mormal forming 6 cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Normal forming 6 cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Mormal forming 6 cutting practice.
PELATIVE COST FACTOR (Hased on ABS Grade A)	1.43	1.43	1.43

TABLE B-3.3 (Continued)

STEEL TYPE & GRADE	Norske Veritas HTS Gr. NVE36	Horske Veritas HTS Gr. NVE40S	Bureau Verites HTS Gr. EH32
	Open-hearth, basic-oxygen,	Open-herth, hasic-oxygen,	Open-hearth, hasic-oxygen,
PROCESS OF MANUFACTURE	or electric-furnace	or electric-furnace	electric-furnace, or any
	process	process	equivalent approved by the society
DECKIDATION	Fully killed	Fully killed	Killed, fine grain
HEAT TREATMENT	Normalized	Normalized	Normalized
CHEMICAL COMPOSITION (Ladie Analysis - %)			
Carbon (max.)	0.18	0,18	0.18
Manganese	0.9 - 1.6	0.09 - 1.6	0.19 - 1.60
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.)	0.04	0.04	0.04
Silicon	0.10 - 0.50	0.10 - 0.50	0.10 - 0.50
Chromium	0.20 max.	0.20 max.	0.20 PAK.
Nickel	0.40 max.	0.40 max.	0.40 max.
Mol ybdenum	0.00 max.	0.00 max.	0.00 max.
Copper	0.35 max.	0.35 max.	0.35 max.
Titanium	ſ	1	l
Vanadium	0.10 max.	0.10 max.	0.10 max.
Alum Laum	0.08 max.	0.08 max.	0.015 - 0.06
Others	0.05 max. Nb	0.05 max. No	0.05 max. Neh
Notes:			
TENSILE REQUIREMENTS			
Ultimate RG/MM ² (RSI)	50 - 63 (71 - 90)	54 - 66 (77 - 94)	45 - 60 (64 - R5)
Yield (min.)KG/HH2 (KS1		40 (57)	32 (45.5)
Elongation (min.) % in	21	20	20
5.65 (A MM (IN) or es noted (A=area of spe.)			
CHARPY V-NOTCH IMPACT TEST			
Temperature °C Energy, KG-M (PT-LB)	-40 3.47 (25) Longitudinal 2.45 (18) Transverse	-40 4.0 (29) Longitudinal 2.65 (19) Transverse	~40 3.16 (23) Longitudina
NUT TEMPERATURE *C			
DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/H IN) THICK SPECIMEN			
ABRASION PESISTANCE AS BRINELL HARINESS	140 - 181	153 - 190	125 - 170
REQUIRED WELDING AND FARMICATION TECHNIQUES	Mulerate preheat for welding, inwehydrogen practice. Normal forming 6 cutting practice.	Moderate preheat for welding, low-hydrogen practice, Normal forming 6 cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Normal forming & cutting practice.
PELATIVE COST FACTOR (Based on ABS Grade A)	1,43	1.41	1.41
	l	J	1

TABLE 8-3.3 (Continued)

STEEL TYPE & GRADE	Bureau Verites	elikik	NKK
	NTS Gr. \$436	#TS Gr. KE32	HTS Gr. KB36
	Open-hearth, besic-oxygen,	Open-hearth, basic-oxygen,	Open-hearth, basic-oxygen,
PROCESS OF HAMUFACTURE	electric-furnace, or any	electric-furnace	electric-furnace
	equivalent approved by the	process, or other approved	process, or other approved
	society	by the society	by the society
DOCK! DATEON	Killed, fine grain	Killed	Killed
HEAT TREATMENT	Mormalized	Normalized	Normalized
CHEMICAL COMPOSITION			
(Ladie Analysis - %)	1	}	ì
Carbon (mgx.)	0.18	0.18	0.18
Manganese	0.90 - 1.60	0.90 - 1.60	0.90 - 1.60
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.)	0.04	0.04	0.04
Silicon	0.10 - 0.50	0.10 - 0.50	0.10 - 0.50
Chromium	0.20 max.	0.20 max.	0.20 max.
Nickel	0.40 max.	0.40 max.	0.40 max.
Mol ybdenum	0.08 max.	0.08 max.	0.00 max.
Copper	0.35 max.	0,35 max.	0.35 max.
Titenium		1	
Vanadium	0.05 - 0.10	i	0.05 - 0.10
Aliminum	0.015 - 0.06	0.015 min.	0.015 min.
(Rhers	0.02 - 0.05 Nb	1	0.02 - 0.05 Mb
	1	i	
Motes:			
TENSILE REQUIREMENTS Ultimate EG/MM ² (KSI)	50 - 63 (71 - 90)	48 - 60 (68 - 85)	50 - 63 (71 - 90)
Yield (min.) KG/MM2 (KSI)		32 (45.5)	36 (51)
Elongation (min.) % in	26	22	21
5.65 (A MM (IN) or an	(
noted (Awares of spe.)			
CHARPY V-MOTCH IMPACT			
TEST Temperature *C	-40	ļ '	l
Energy, KG-M (PT-LB)	-40 3-5 (25) Longitudinel	-40 3.2 (23) Longitudinal 2.3 (17) Transverse	-40 3.5 (25) Longitudinal 2.5 (18) Transverse
NUT TEMPERATURE *C			
DYMAMIC TEAR EMERGY IN RG-M (FT-LB) AT 24°C FUR 16 MM (5/8 IN) THICK SPECIMEN			
ABRASION PESISTANCE AS BRINELL, HARDNESS	140 - 181	135 - 170	140 - 181
REGITATION TECHNIQUES	Moderate preheat for welding. Enw-hydrogen practice. Normal forming and cutting practice.	Moderate preheat for welding, Low-hydrogen practice. Normal forming 6 cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Normal forming 6 cutting practice.
PETATEVE COST PACTOR (BARR) ON ABS (BARR)	1.43	1.43	1.43

TABLE 8-3.3 (Continued)

PROPERTIES OF STEELS USED FOR ICE-STRENGTHENED SHIPS

STEEL TYPE & GRADE	German. Lloyd	German. Lloyd	ASTM-A633
	MTS Gr. 832 Open-hearth, healc-oxygen,	NTS Gr. E36 Open-hearth, hesic-oxygen,	Gr. C Open-hearth, basic-oxygen
PROCESS OF MANUFACTURE	electric-furnace, or any	electric-furnace, or any	or electric-furnace
	equivalent approved by the	equivalent approved by the	process
	society	society	J P. 33333
DECKIDATION	Killed	Killed	Pine grain practice
HEAT TREATMENT	Normalized	Normalized	Normalized
CHEMICAL COMPOSITION			
(Ladle Analysis - %)			
Carbon (max.)	0.18	0.18	0.20
Manganese	0.90 - 1.60	0.90 - 1.60	1.15 - 1.50
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.)	0.04	0.04	0.05
Silicon	0.10 - 0.50	0.10 - 0.50	0.15 - 0.50
Chromium	0.20 max.	0.20 max.	
Nickel	0.40 max.	0.40 max.	
Mol ybdenum	0.08 max.	0.08 max.	1
Соррег	0.35 max.	0.35 max.	
Titanium			1
Vanadium			1
Aliminum	0.02 - 0.47	0.05 - 0.10	
Others		0.02 - 0.07	0.01 - 0.05 Ct
Notes:		0.02 - 0.05 Nb	
TENSILE REQUIREMENTS Ultimate KC/MM ² (KSI) Vield (min.)KC/MM ² (KSI) Elongation (min.) % in 5.65 ,K MM (IN) or as noted (A=area of spe.)	48 - 60 (68 - 85) 32 (45.5) 22	50 - 63 (71 - 90) 36 (51) 21	49 - 63 (70 - 90) 35 (50) 23 in 51 MM (2 IN)
CHARPY V-NOTCH IMPACT TEST Temperature °C Energy, KG-M (FT-LB)	-40 3.2 (23) Longitudinel 2.4 (17) Transverse	-40 3.5 (25) Longitudinal 2.2 (16) Transverse	-46 3.5 (25) Longitudin 2.6 (20) Transverse
	2.4 (17) Itansverse	2.2 (10) Itanavarae	
NIT TEMPERATURE *C			-57 Aver.
DYNAMIC TRAN ENERGY IN KG-M (PT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN			
ABRASION RESISTANCE AS BRINELL HARINESS	135 - 170	140 - 181	137 - 181
REQUINED WELLING AND FARPICATION TECHNIQUES	Moderate preheat for welding, Low-hydrogen practice. Mormal forming and cutting practice.	Moderate preheat for welding. Low-hydrogen practice. Mormal forming and cutting practice.	Noderate preheat for welding. Low-hydrogen practice. Normal forming 6 cutting practice.
PELATIVE COST PACTOR Chased on ABS Grate At	1.41	1.43	1.43

TABLE B-3.3 (Continued)

STEEL TYPE & GRADE	ASTN-A678		
STEEL TYPE & GRADE		ABS Low - Temp. Gr. V-039	ABS Low - Temp.
	Gr. A		Gr. V-051
PROCESS OF HAMUFACTURE	Open-hearth, hesic-oxygen, or electric-furnace	Open-hearth, hasic-oxygen, or electric-furnace	Open-hearth, hasic-oxygen, or electric-furnace
PROCESS OF MANUFACTURE	process		
	process	process	process
DECKIDATION	Fine grain practice	Fine grain practice	Pine grain gractice
		rane gran practice	
HEAT TREATMENT	Quenched & tempered	Normalized	Hormalized
CHEMICAL COMPOSITION	1		
(Ladie Analysis - %)	ł		
(reute westAsts - 4)			
	•	1	ļ
		4	
	1	j	
Carbon (max.)	0.16	0.20	0.16
Manganasa	0.90 - 1.50	0.90 - 1.35	1.15 - 1.50
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.)	0.05	0.04	0.04
Silicon	0.15 - 0.50	0.10 - 0.35	0.10 - 0.35
Chronium		0.25 max.	0.25 max. 0.80 max.
Hickel	!	0.80 max. 0.08 max.	0.80 max. 0.08 max.
Rolybdenum Copper	0.20 - 0.35*	0.08 max. 0.35 max.	0.05 max. 0.35 max.
Copper Titenium	0.20 - 0.35	, V.37 Max.	U. 15 Max.
Titanium Vanadium	1	0.10 max.	0.10 max.
Aluminum	{	0.065 max.	0.065 max.
Others		0.05 max. Cb	0.05 max. Cb
inches 5		1	3,10, 110, 10
Notes:	*When specified		
		1	
		1	
		1	
	Į.	l	
		ŀ	
		<u> </u>	
TENSILE REQUIREMENTS	ł .		
Ultimate NG/MH ² (KSI)	49 - 63 (70 - 90)	41 - 63 (58 - 90)	41 - 63 (58 - 90)
Yield (min.) RG/1012 (RSI)	35 (50)	25 (36)	25 (36)
Elongation (min.) % in	33 (30)	22 (36)	23 (30)
5.65 (A MM (IN) or as	in 51 MM (2 IN)	<u></u>	••
noted (Awares of spe.)	,,	ì	
	<u> </u>		
CHARPY V-HOTCH IMPACT	Purchaser specs.	1	
TEST)		
Temperature *C	-73	-39	-51
Energy, RG-M (PT-LB)	2.8 (20) Longitudinal	3.5 (25) Longitudinal	
	2.0 (14) Transverse	2.3 (17) Transverse	2.3 (17) Transverse
NOT TEMPERATURE *C	-62 aver.	-57 aver.	-57 aver.
THE CAMPAGE C]	-3, 4,4,	-37 6761.
DYNAMIC TEAR ENERGY	1		
IN NG-M (PT-LB) AT 24°C	F	1	
POR 16 PM (5/8 IN)	1	l	
THICK SPECIMEN	i	I	
ABRASION RESISTANCE AS	138 - 161	110 - 181	110 - 181
BRINELL HARDNESS	I		
	Controlled welding	Preheat required, if	Preheat required, if
RECILIRED WELDING AND	process. Moderate	ambient temp. below 0°C	ambient temp. below 0°C
FABRICATION TECHNIQUES	preheat. Low-hydrogen	Low-hydrogen practice.	Low-hydrogen practice.
	practice. Normal forming	Selected electrodes.	Selected electrodes.
	6 cutting practice.	Normal forming & cutting	Hormal forming & cutting
		practice	practice
RELATIVE COST FACTOR	1.46	1.46	1.46
(Mased on ARS Grade A)	l]	
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TABLE B-3.3 (Continued)

STEEL TYPE & GRADE	ASTH-A678	ASTM-A633	ASTM-A678
	Gr. D	Gr. E	Gr. C
PROCESS OF HANUFACTURE	Open-hearth, basic-oxygen, or electric-furnace	Open-hearth, hasic-oxygen, or electric-furnace	Open-hearth, besic-oxygen, or electric-furnace
·	process	process	process
DEOXIDATION	Pine grain practice	Fine grain practice	Fine grain practice
HEAT TREATMENT	Quenched & tempered	Hormalized*	Quenched & tempered
CHEMICAL COMPOSITION	}	1	
(Ledle Analysis - %)			
Carbon (mex.)	0.20	0.22	0.22
Manganese	0.70 - 1.35	1.15 - 1.50	1.00 - 1.60
Phosphorus (max.)	0.04	0.04	0.04
Sulphur (max.) Silicon	0.05	0.05	0.05
Siticon Chromium	0.15 - 0.50 0.25 max.	0.15 - 0.50	0.20 - 0.50
Nickel	0.25 max.		0.25 max.
Mol yhdenum	0.08 max.		0.25 max. 0.00 max.
Copper	0.20 - 0.35*		0.20 - 0.35*
Titanium	l		0.20 - 0.13
Venedium		0.04 - 0.11	
Aluminum			
Others		0.01 - 0.03 Witrogen	
Wites:	*When specified	*Double normalized above 76 NN (3 TN).	*When specified
TENSILE REQUIREMENTS	<u> </u>		For 38 MM (1.5 IN) incl.
Ultimate NG/HH2 (RSI)	56 - 70 (80 - 100)	56 - 70 (80 - 100)	63 - 77 (90 - 118)
Yield (min.) RG/MM ² (RSI) Elongation (min.) % in	42 (60) 22	42 (60) 23	49 (70) 19
5.65 (AM (1M) or as	in \$1 MM (2 IN)	in 51 MM (2 IN)	in 51 MM (2 IN)
noted (A=area of spe.)		1	
CHARPY V-NOTCH IMPACT TEST	Purchaser Apecs.		Purchaser Speca.
Temperature °C Energy, KG-M (FT-LB)	-73 2.0 (14) Longitudinal	-40 3.5 (25) Longitudinal	-73 2.8 (20) Longitudinal
Energy, NO-H (FT-LB)	1.4 (10) Transverse	2.8 (20) Transverse	2.0 (14) Transverse
MIT TEMPERATURE *C	-57 aver.	-46 ever.	-73 to -68
DYNAMIC TEAR ENERGY IN KG-M (FT-LB) AT 24°C POR 16 MM (5/8 IN) THICK SPECIMEN			
ADRASION RESISTANCE AS DRINELL, HARONESS	159 - 202	159 - 202	101 - 221
REQUIRED MELDING AND PARRICATION TECHNIQUES	Controlled wolding process. Moderate preheat. Low-hydrogen practice. Mormal forming A cutting practice.	Controlled welding process. Moderate preheat. Low-hydrogen practice. Normal forming and cutting practice.	Controlled welding process with prohesting. Low-hydrogen practice. Selected electrodes. Moreal forming & cutting ptactice.
RELATIVE COST PACTOR (Based on ABS Grade A)	1,40	1.49	1.50

TABLE B-3.3 (Continued)
PROPERTIES OF STEELS USED FOR ICE-STRENGTHENED SHIPS

STEEL TYPE & GRADE	ASTN-A537 Class 2	A87M-A737	CG-A537
PROCESS OF MANUFACTURE	Open-hearth, hasic-oxygen, or electric-furnace process	Gr. B Open-hearth, besic-oxygen, or electric-furnace process	Gr. M Open-hearth, hesic-oxygen, or electric-furnace process
DECKIDATION	Fine grain practice	Killed, fine grain practice	
HEAT TREATMENT	Quenched & tempered	Mormalized	Quenched & tempered
CHEMICAL COMPOSITION (Ladle Analysis - %)			
Carbon (max.) Manganese Phosphorus (max.) Sulphur (max.) Silicon Chromium Mickel Mnlybilenum Copper Titanium Vanadium Aluminum	0.24 0.70 - 1.35 0.035 0.040 0.15 - 0.50 0.25 max. 0.25 max. 0.00 max.	0.22 1.10 - 1.55 0.035 0.035 0.035	0.16 0.90 - 1.50 0.035 0.040 0.15 - 0.35 0.25 max. 0.25 max. 0.35 max.
Others Moten:		0.05 m.v. 19	
TEMSILE MEQUIPMENTS Ultimate MG/MM ² (KSI) Yield (min.)MG/MM ² (KSI) Elongation (min.) & in 5.65 j R MM (IN) or as noted (A-area of ape.)	56 - 70 (80 - 100) 42 (60) 22 in 51 MM (2 IN)	49 - 63 (70 - 90) 35 (50) 23 in 51 MM (2 IN)	49 - 63 (70 - 90) 35 (50) 22 in 51 MM (2 IN)
CHARPY V-NOTCH IMPACT TEST Temperature *C Energy, KG-M (PT-LD)	-60 2.† (15) Longitudinel	-46 3.5 (25) Longitudinal 2.8 (20) Transverse	-51 2-8 (20) Transverse
NUT TEMPERATURE °C	-62 to -51		-62 aver.
DYNAMIC TEAR EMERGY IN KG-M (FT-LB) AT 24°C FOR 16 MM (5/8 IN) THICK SPECIMEN	76 (550)		
ABRASI'M RESISTANCE AS BRINKLI. HARIMESS	159 - 202	137 - 181	138 - 161
REQUIRED WELDING AND PARRICATION TECHNIQUES	Controlled welding process. Moderate preheat. Low-hydrogen practice. Mormal forming a cutting practice.	Roderate preheat for welding, Low-hydrogen practice. Mormal forming 4 cutting practice.	Controlled welding process. Moderate preheat. Low-hydrogen practice. Normal forming 6 cutting gractice.
PELATIVE COST FACTOR (Based on ABS Grade A)	1,51	1.51	1.52

TABLE B-3.3 (Continued)

STEEL TYPE 6 GRADE	ASTM-A710	MA-80	HY-100
	Gr. A Class 3 Open-hearth, hasic-oxygen,	MIL-S-16216H Open-hearth, hasic-oxygen,	MIL-S-16216H
PROCESS OF HAIRUPACTURE	or electric-furnace	or electric-furnace	Open-hearth, hasic-oxygen, or electric-furnace
	process	process	process
	<u> </u>		, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
DECKIDATION	Killed, fine grain practice		
MEAT TREATMENT	Quenched & tempered	Quenched & tempered	Quenched & tempered
CHRICAL COMPOSITION	ł		
(Ladle Analysis - %)	ì		i
,		İ	1
	ł	l ·	ł
		·	
Carbon (max.)	0.07	0.10	0.20
Hanganess	0.40 - 0.70	0.10 - 0.40	0.10 - 0.40
Phosphorus (max.)	0.025	0.025	0.025
Sulphur (max.)	0.025	0.025	0.025
Silicon	0.40 max.	0.15 - 0.35	0.15 - 0.35
Chromium	0.60 - 0.90	1.00 - 1.00	1.00 - 1.80
Hickel	0.70 - 1.00	2.00 - 3.25	2.25 - 3.50
Mol ybdenun	0.15 - 0.25	0.20 - 0.60	0.20 - 0.60
Copper Titanium	1.00 - 1.30	0.25 max.	0.25 max.
Venedium		0.02 max. 0.03 max.	0.02 max. 0.03 max.
Aluminum	ł	U.U. mex.	U.US MAR.
Others	0.02 min. Cb		
Notes:	(
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TEMBILE REQUIREMENTS	For 25.4 MM (1 IM) incl.		
Ultimete NG/HH ² (KSI)	60 (85)	70 (100) min.	81 (115) min.
Yield (min.)KG/1012 (KS1)		56 (80) 20	70 (108) 18
Blongation (min.) % in 5.65 ja Mel (IN) or as	20 51 MM (2 IN)	in 51 MM (2 IM)	in 51 994 (2 19)
noted (Aparea of spe.)	3, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2,	111 31 100 (2 111)	
moter (moter of aper)			
CHARPY V-NOTCH IMPACT	Į.		
TEST	Į.		}
Temperature *C	-62	-94	-84
Energy, KG-M (FT-LB)	6.9 (50) Longitudinal	6.9 (50)	6.9 (50)
	4.8 (35) Transverge		
NUT TEMPERATURE *C	-73 aver.	-107 aver.	
	<u> </u>		
DYNAMIC TEAR ENERGY	}		
IN NG-M (FT-LB) AT 24°C FOR 16 MM (5/8 1M)	140 (1012)		ŀ
THICK SPECIMEN	140 (1012)		l
	i .		
	}		J
ABRASION RESISTANCE AS		201	233
DRINELL HARIMESS	170		l
	Little or no preheat	Careful control of	Careful control of
REQUIRED WELDING AND	requirements for welding.	welding process. Costly	welding process. Costly
PARRICATION TECHNIQUES	Special electrodes.	electrodes. Additional	electrodes. Additional
100 100 100 100 100 100 100 100 100 100	Plates can be fabricated	forming power. Plate tamp.	forming power. Plate temp.
	in the as-rolled condition.	for flame cutting not	for flame cutting not
		below 10°C.	below 18°C.
	1]
RELATIVE COST FACTOR (Mased on ABS Grade A)	2,51	3.11	3.21
((.)	l ''''	l "''
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APPENDIX B-4
TABULAR WEIGHT AND COST DATA

TABLE 8-4.7 TYPICAL MIDBODY PAMEL WEIGHTS & COSTS - POLAR STAR (Panel Height = 8.5 ft)

CLASS	STIFF. SPCG.	PLTG. THCK.	STIFF.	STIFFENER SIZE	% CHG. WGT.	% CHG.
ABS #A1, C; Lloyds 3; DNV ICE C; BV III; USSR A3,A4: PRC BIII	26	0.40	6	5" x 3-1/2" x 1/4" t	00	00
USSR A2; PRC BII; BV []	26	0.45	6	5" x 3-1/2" x 1/4" L	10.4	10.4
ABS 1C	26	0.50	6	5" x 3-1/2" x 1/4" L	20.9	20.9
ABS B; Lloyds 2	26	0.55	6	5" x 3-1/2" x 1/4" L	31.3	31.3
ABS IB: NKK B.C	26	0.70	6	5" x 3-1/2" x 1/4" L	62.6	62.6
ASPPR 1: ABS 1A	26	0.75	22	8" x 4" x 1/2" L	102.7	102.7
ABS IAA	26	1.00	22	8" x 4" x 1/2" L	136.9	136.9
ASPPR 2	26	1.55	87	13-3/4" x 8" x 48# I-T	301.3	301.3
ASPPR 4	26	2.00	145	16-3/8" x 10-1/4" x 67# I-T	423.1	423.1
ASPPR 7	26	2.25	186	21-1/4" x 8-1/4" x 73# I-T	496.9	496.5
ASPPR 10	26	2.35	208	21-3/8" x 8-3/8" x 83# I-T	533.9	533.
ASPPR 1	16	0.60	15	7" x 4" x 3/8" L	77.1	77.9
NKK A	16	0.80	15	7" x 4" x 3/8" L	118.8	120.0
ASPPR 2: NKK AA	16	0.90	30	8" x 6" x 1/2" L	175.8	177.0
DIV Icebreaker	16	1.10	30	9" x 4" x 1/2" L	211.0	213.
DNV Arctic Icebreaker	16	1.45	30	9" x 4" x 1/2" L	284.0	286.8
ASPPR 2	16	0.95	54	12-1/2" x 6-1/2" x 35# 1-T	190.0	191.9
ASPPR 4	16	1.25	90	13-7/8" x 8" x 53# 1-T	300.5	303.
ASPPR 7	16	1.40	116	14" x 10" x 68# 1-T	365.6	369.
ASPPR 10	16	1.45	129	18-1/4" x 7-1/2" x 60# [-T	370.3	374.0
ABS A; Lloyds 1; USSR A1; BV 1; PRC B1	13	0.50	6	4" x 3-1/2" x 3/8" L	47.2	48.
l layds 1*, PRC BI*	13	0.55	6	5" x 3-1/2" x 1/4" L	47.6	48.6
BV 1-Super	13	1.25	6	5" x 3" x 1/4" Ł	192.0	195.6
HSSR YA	13	0.55	10	6" x 4" x 5/16" L	63.4	64.

TABLE 8-4.2

TYPICAL MIDBODY PAMEL WEIGHTS & COSTS - MV ARCTIC (Panel Height = 27 ft)

CLASS	STIFF. SPCG.	PLTG. THCK.	STIFF. S.M.	STIFFENER SIZE	% CHG. WGT.	% CHG.
ABS +A1, C, IC; Lloyds 2, 3; ONV ICE C; BY III; USSR A3, A4;						
MKK C; PRC BIII	33	0.67	117	18-1/8" x 7-1/2" x 55# I-T	00	00
BV 11; USSR A2; PRC BII	33	0.75	117	18-1/8" x 7-1/2" x 55# 1-T	7.8	7.8
ABS B, IB; NKK B	33	0.90	117	18-1/8" x 7-1/2" x 55# I-T	22.3	22.3
ASPPR 1	33	1.00	117	18-1/8" x 7-1/2" x 55# I-T	32.1	32.1
ABS IA	33	1.05	117	18-1/8" x 7-1/2" x 55# I-T	36.9	36.9
ABS IAA	33	1.15	122	18-1/8" x 7-1/2" x 55# I-T	46.6	46.6
ASPPR 2	33	1.60	260	24-1/4" x 9-1/8" x 94# I-T	115.8	115.8
ASPPR 4	33	2.25	530	33-1/4" x 11-1/2" x 141# I-T	211.0	211.0
ASPPR 7	33	2.70	750	36-3/8" x 12-1/8" x 182# I-T	282.3	282.3
ASPPR 10	33	3.00	950	35-7/8" x 16-1/2" x 230# I-T	334.6	334.0
DNY Icebreaker	20	0.70	1161	T-52" x 1" Web, 11-1/2" x 1-1/4" Fig.	290.6	299.4
DNV Arctic Icebreaker	20	1.00	1451	T-52" x 1" Web, 11-1/2" x 1-3/4" Flg.	347.7	358.
ASPPR 1	17	0.50	50	12" x 9" x 15.3# Flg. Plt.	- 7.2	- 5.3
USSR A2	17	0.85	80	13-5/8" x 8" x 43# I-T	38.1	38.
NKK A	17	0.95	90	16-1/4" x 7-1/8" x 50# 1-T	48.4	49.
Lloyds 1	17	0.67	117	15" x 8" x 30.6# Flg. Plt.	60.5	61.1
Lloyds 1*	17	0.75	117	15" x 8" x 30.6# Flg. Plt.	68.3	69.
PRC BI BV I	17	0.80	117	18-1/4" x 7-1/2" x 60# I-T	51.3	52.
ABS A: USSR YA: PRC BI*	17	0.85	117	18-1/4" x 7-1/2" x 60# 1-T	56.2	57.
BY 1-Super	17	1.20	117	18-1/8" x 7-1/2" x 55# 1-T	84.3	86.
ASPPR 2	17	0.80	130	18" x 8" x 25.5# Flg. Plt.	68.4	69.
NKK AA	17	1.05	130	24" x 6" x 17.85# Flg. Plt.	76.1	77.
ASPPR 4	17	1.15	266	T-15" x 1" Web, 8" x 2" Fig.	189.0	196.
ASPPR 7	17	1.35	376	T-20" x 1" Web, 8" x 2" Flg.	237.0	246.
ASPER 10	12	1.50	476	T-22" x 1" Web, 8" x 2-1/4"	274.5	285.

TABLE 8-4.3

TYPICAL MIDBODY PANEL WEIGHTS & COSTS - ARCTIC TANKER (Panel Height = 7.5 ft)

CLASS	STIFF. SPCG.	PLTG. THCK.	STIFF. S.M.	STIFFENER SIZE	% CHG. WGT.	% CMG.
ABS +A1, B, C, IB, IC; Lloyds 2, 3; DNV ICE C: BV II. III; USSR A2, A3,						
A4; MKK C; PRC BIII	40	1.05	38	10-1/2" x 5-3/4" x 30# 1-T	00	OC.
MKK 8	40	1.10	38	10-1/2" x 5-3/4" x 30# I-T	4.2	4.2
PRC 811	40	1.15	38	10-1/2" x 5-3/4" x 30# I-T	6.3	8.3
ABS IA; ASPPR 1	40	1.20	38	10-1/2" x 5-3/4" x 30# I-T	12.5	12.9
ABS TAA	40	1.35	38	10-1/2" x 5-3/4" x 30# I-T	25.0	25.0
ASPPR 2	40	2.35	106	18" x 6" x 20.4# Flg. Plt.	119.9	119.9
ASPPR 4	40	3.05	175	21" x 8-1/4" x 62# 1-T	181.9	181.9
ASPPR 7	40	3.45	226	23-7/8" x 9" x 76# [-T	221.7	221.
ASPPR 10	40	3.65	252	24-1/8" x 9" x 84# I-T	246.2	246.
DNV Icebreaker	28	2.55	61	12" x 8" x 40# I-T	135.5	136.
DNV Arctic Icebreaker	28	3.60	77	15" x 3-3/6" x 40# C-L	228.7	231.
ASPPR 1	20	1.05	13	8" x 4" x 13" I-T	- 0.7	1.
ABS A; Lloyds 1; BV I	20	1.05	38	12-1/4" x 6-1/2" x 26# I-T	11.2	11.
Lloyds 1°; BY I-Super; PRC BI, BI*	20	1.25	38	12-1/4" x 6-1/2" x 26# I-T	27.9	28.
USSR A1	20	1.35	38	12-1/4" x 6-1/2" x 26# I-T	36.2	36.
ASPPR 2	20	1.20	53	9-1/8" x 7-1/2" x 30# T	36.5	37.
NKK A	20	1.20	66	14-1/8" x 6-3/4" x 38# I-T	32.9	33.
ASPPR 4	20	1.50	88	12" x 9" x 38# T	71.3	72.
NKK AA; USSR YA	20	1.30	99	18" x 6" x 20.4# Flg. Plt.	57.0	58.
ASPPR 7	20	1.70	113	16-3/8" x 7-1/8" x 57# I-T	92.2	94.
ASPPR 10	20	1.80	127	21" x 6" x 20.4# Flg. Plt.	104.8	106.

APPENDIX C REVIEW OF METHODS FOR DAMAGE ANALYSIS

1. INTRODUCTION

The objective of this part of the study is to identify and review currently available methods for analyzing ship damage; that is to determine the external ice loads which caused the hull failure. A complete identification of such loads acting normal to the shell plating requires knowledge of:

- the area of action
- the pressure distribution within this area.

These variables can be used to calculate the average pressure distribution and the total load.

There is no method, within the state-of-the-art, which can be used to determine the ice pressure distribution. Therefore, it is common to assume a uniform pressure within the contact area. Nonetheless, the influence of pressure distribution is thought to have significant effects on the unevenness of load distribution on the hull structure. The assumption of uniform pressure on a small plate panel is, on the other hand, quite acceptable.

In most damage incidents, if not all of them, an analyst is bound to make some assumptions as to how the damage occurred. Although simple damage analysis techniques do not require elaborate data and it is often sufficient to have the structural detail, knowledge of the damage circumstances is essential to the understanding of such occurrences. For instance, in order to justify the damage location, one should know the operating draft and trim of the ship, ice thickness, type of ice, and possible physical description.

The review of damage analysis methods is divided into two sections: the first is concerned with simple techniques which attempt to predict the uniform failure pressures without regard to how it occurred, while the second section is devoted to proposing a more detailed approach to study ice damage.

2. SIMPLE METHODS

The simplest approach considers the failure of basic components of the hull under uniform pressure. For instance, consider a long plate panel supported along its four sides by frames and stringers and subjected to uniform lateral pressure. The maximum pressure required to cause one of the following conditions can be estimated:

- · reach the elastic limit.
- · cause one plastic hinge at the center,
- · cause two plastic hinges at the supports,
- cause three plastic hinges, one at the center and two at the supports,
- · cause plate rupture due to membrane tension, etc.

Therefore, the criterion of failure is important to define and various methods will now be reviewed.

2.1 Elastic Method

Considering the standard plate panel fixed at all edges and subjected to uniform pressure over the entire plate, the maximum pressure for the stress at the center of the support, not to exceed the elasticity limit, is given in any standard elasticity handbook, e.g. [E-27], as follows:

$$p = \frac{1}{\beta} \sigma_y \cdot (\frac{t}{s})^2$$

where

 σ_y = the yield strength of the material (2400 kp/cm² for structural steel = 35000 psi)

t =the plate thickness

s = the spacing between long edges or frames

 β = is a coefficient = 0.5 for an aspect ratio > 2

Therefore.

$$p = 2 \sigma_y \left(\frac{t}{s}\right)^2 \tag{C.1}$$

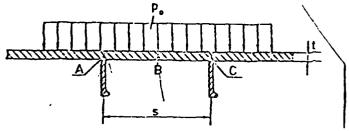
2.2 Elastic - Perfectly Plastic

The simplest method for damage analysis is the so-called plastic method proposed by Johansson in 1967 [E-13]. The method is based on the premise that a permanent set does not occur until three plastic hinges develop; one at each support and one at the center of the plate as shown in Figure D.la. The minimum uniformly distributed pressure, p, required to satisfy this condition, is given by:

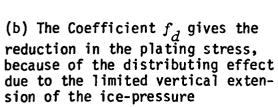
$$p = 4 \sigma_y \frac{t^2}{s^2} \cdot \frac{1}{f_d}$$
 (C.2)

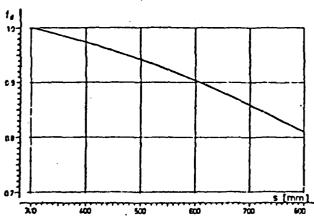
FIGURE D.1 PLASTICITY METHOD FOR DAMAGE ANALYSIS

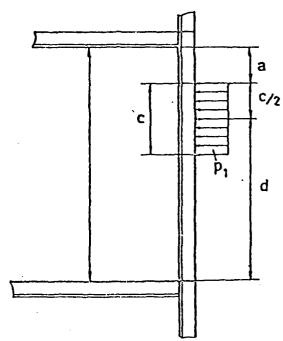
(a) Definition of Plate Calculations



(c) Definitions of Frame Calculations







where

p = the maximum pressure the plating can carry without onset of plastic deformation, kp/cm^2

 σ = the yield strength of the plate material, kp/cm² (~2400 kp/cm for mild steel)

t = the plate thickness, mm

s = the frame spacing, mm

 f_d = a correction factor which accounts for frame spacing and is given in Figure C.1(b).

The maximum pressure the frames can accommodate without plastic hinge formation, p_1 , is expressed by:

$$p_{1} = \frac{2000 \, \sigma_{y} \, W_{p} \, \ell}{c.s.d. \, (a + c.d/2\ell)} \tag{C.3}$$

where

 $W_{_{\mathcal{D}}}$ = the plastic section modulus, cm³ (which includes plate portion)

 ℓ = the span of the frame, m

c = the width of ice pressure, usually taken as maximum ice thickness, mm

a & d are illustrated in Figure C.1(c)

For $d = \ell/2$, the frame stresses will be maximum and the pressure reduces to:

$$p_1 = \frac{16000 \text{ } \sigma \cdot \text{ } W}{c \cdot s \text{ } (2l - c)} \tag{C.4}$$

Johansson used this method to determine the maximum pressure which would have caused hull damage for 200 ship damage cases. The damage pressure estimated by this method is based on an assumed standard contact area extending over at least two frame spacings and the full depth of ice assumed to be 800 mm.

The major criticism for this method is the fact that it does not take into account in-plane tension or membrane effects of the plate.

2.3 Plastic Method with Membrane Effect

This method was proposed by Clarkson [E-6] in 1956. It is applicable to plate design and retains the influence of geometry changes and thus, takes into account membrane forces and their effect on increasing the load carrying capacity. Assuming uniformity, the pressure corresponding to one plastic hinge is given by:

$$p = 4.56 \left[\sigma_y^{4/3} / E^{1/3} \right] \cdot \left(\frac{t}{s} \right)^{4/3}$$
 (C.5)

where

E = the elastic modulus of the hull plate material and other variables are previously defined.

Archtarides [E-1] used the data reported by Johansson [E-13] to calculate (t/s) and, then, used equation (C.5) to estimate ice pressures and propose different design curves.

In fact, a direct comparison between equations (C.5) and (C.2) is not possible because each one is based on different failure criterion. For the pressure to cause three plastic hinges with consideration of membrane effect, equation (C.5) should be corrected by approximately a factor of 2 to read:

$$p = 9.12 \left[\sigma_y^{4/3}/E^{1/3}\right] \cdot \left(\frac{t}{s}\right)^{4/3}$$
 (C.6)a

Rearranging (.6)a obtain:

$$p = \left| 4 \sigma_y \left(\frac{t}{s} \right)^2 \right| \cdot \left| 2.28 \sqrt[3]{\left(\frac{\sigma_y}{E} \right) \cdot \left(\frac{s}{t} \right)^2} \right|$$
 (C.6)b

Comparing (C.6) with (C.2) for structural steel and $S/t \approx 10$ it appears that consideration of membrane effects increases the pressure load capacity by approximately 11-12%. This ratio would increase for high strength steels as well as higher spacing to thickness ratios. It is equally true that for thick steel with closely spaced framing, the membrane effects will be negligible.

2.4 Empirical Pressure Distribution Method

This method is based on empirical grounds proposed by Kheysin [B-18]. He suggests that due to the flexibility of the shell, ice pressure will be distributed as illustrated in Figure C.2. The maximum load on transverse frames is:

$$P = q_O \cdot a \tag{C.7}$$

where

$$q_o = \sigma_c \cdot h/2$$
; $\sigma_c = \text{ice crushing strength}$

h = thickness

$$\alpha$$
 = 3.3 $\sqrt[3]{\frac{E_s}{E_i} \cdot \frac{I_s}{\ell}}$; E_s = elasticity of the hull steel E_i = elasticity of ice I_s = section moment of inertia of the stringer ℓ = spacing between bulkheads

This method can be used to assess the pressure distribution that caused damage if used in conjunction with a plastic failure criterion such as Johansson's. We should write:

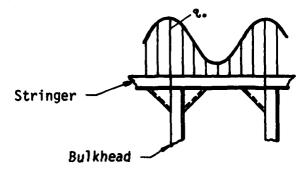
$$P = p_1 \cdot h \cdot S \tag{C.8}$$

where p_1 can be obtained from equation (C.4). By working back a, obtain q_O and estimate σ_O under actual conditions of interaction. However, it should be noted that the method pertains to bulkheads and stringers in the middle body of a ship, and it is not clear to us how this method can be applied to analysis of main frames with

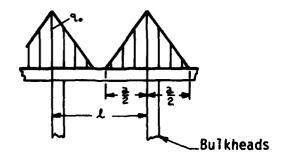
FIGURE C.2

ICE PRESSURES ON THE HULL

(a) Actual Pressure Distribution



(b) Idealized Distribution



proper account of pressure distribution effects. One possible way is to set limits on the value of α in equation (C.7).

2.5 Plastic Energy Method

Plastic analysis procedure was developed by McDermott, et al [E 24] for the analysis of tanker collision. Although the procedure, which is based on model tests and inspection of collision damage, was never extended to ice damage, it is potentially useful in this regard. The approach is based on the calculation of plastic energy components up to the incidence of hull rupture. This primarily involves three phenomena producing plastic deformation: longitudinal plastic bending of the stiffened hull plating, plastic membrane tension in the stiffened hull plating, and yield or buckling of the web frames (and/or swash bulkheads). Figure C.3 shows the possible sequences of these three phenomena for a single hull ship while Figure C.4 is concerned with a double hull ship. The authors suggested that most of the energy absorbed in collision (67 to 90%) is due to membrane tension in the stiffened hull. Therefore, damage is expected to initiate where less energy is required, e.g. bend and buckle stiffeners. The latter would enhance plate deformation through a loss of support and ultimately lead to shell failure. This scenario can be supported by the nature of damage due to ice observed on the MV ARCTIC.

Unfortunately, the formulas provided by McDermott, et al are only applicable to concentrated line load (due to ship incursion into another) and it is not suitable for any damage analysis due to ice. Attempts to test his method in case of ice damage proved it to produce unrealistic estimates of ice pressures and tremendous loads which can only exist in ship collision situations.

Nonetheless, his approach is one step ahead as he incorporates the effects of in-plane membrane effects. This leads to a higher hull loading capacity and within the context of damage analysis should produce higher ice pressure estimates.

Further development of plastic damage analysis procedures along these lines is highly recommended.

2.6 Case Study

The foregoing discussion is limited to one approach to the problem which uses the reverse of design criteria. It is capable only of suggesting what uniform pressure applied in a prescribed fashion on the hull plating would have caused structural failure. However, it remains the simplest and it can lead to some explanation of failure incidents.

To illustrate this, let us examine the damage inflicted by ice on the MV ARCTIC and attempt to predict ice pressures in accordance with the methods described in this section.

The damage is described by Laskey [G-11] and reproduced in the sketch shown in Figure C.5. The following details may be used:

$$t = 1.063$$
"

S = 12.0" (for intermediate frames)

$$W_p = 94.7 \text{ in}^3$$

FIGURE C.3

FLOW DIAGRAM FOR SIDE-COLLISION PLASTIC-ENERGY ANALYSIS OF SINGLE-HULL SHIP

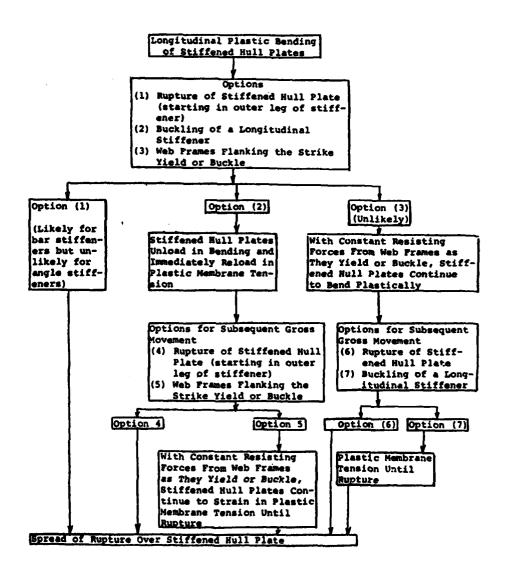


FIGURE C.4

FLOW DIAGRAM FOR SIDE-COLLISION PLASTIC-ENERGY ANALYSIS OF A DOUBLE-HULL SHIP

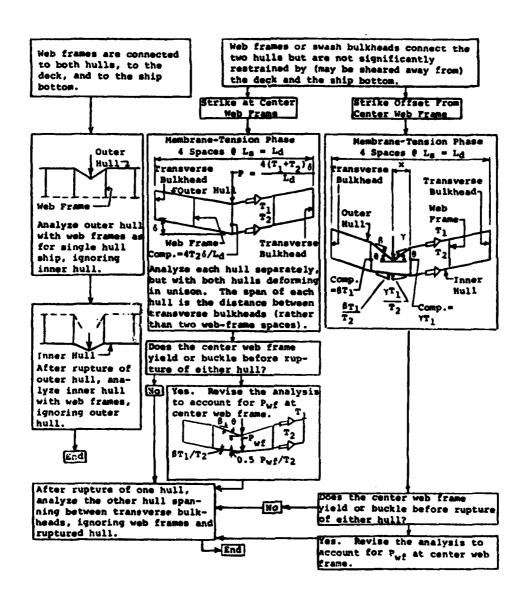
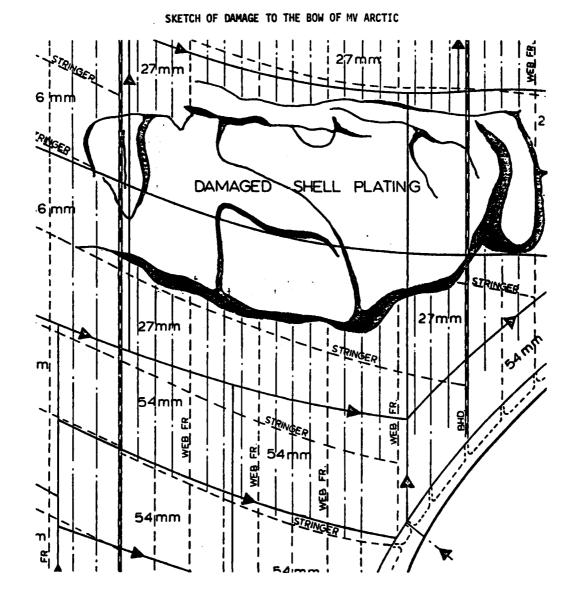


FIGURE C.5



$$\ell = 48"$$
 $\sigma_y \simeq 35,000 \text{ psi}$
 $f_d = 1$
 $h \simeq 40"$

Obtain from equation (C.1) elastic method	p	=	549	psi	(3.79	MPa)
(C.2) Johansson's (plate)			1099	psi	(7.75	MPa)
(C.4) Johansson's (frames)			2019	psi	(13.9	MPa)
(C.5) Clarkson's method [21% higher than Eq.(C.2)			1327	psi	(9.15	MPa)

Therefore, the ice pressure which can cause failure to the plates is 1327 psi according to Clarkson while that required to cause frame damage, is 2019 psi. These figures are well in excess of the maximum rule design pressure of 600 psi set by ASPPR for Arctic Class 2 ships. While ice pressures of the order of 600 psi would not cause any structural damage or permanent deformation, it is obvious that the ship was subjected to an overload.

These results, obtained in comparison with the most conservative and most comprehensive design rules, i.e. the Canadian ASPPR, raise some questions relating to the adequacy of design pressures. However, it is essential to complete the entire scenario which gave rise to such high pressure. It may, indeed, have been a collision case with a fairly low probability of occurrence.

This leads us to the brief introduction of an alternative approach which is more detailed and it takes into consideration the scenario and circumstances of damage incident.

3. ALTERNATIVE APPROACH

This approach consists of several steps:

- (1) Identify possible scenarios of interaction between ship and ice feature as well as data on ice type, strength, size, shape, etc.
- (2) Run a computer simulation of the interaction scenario with proper input data and variations of angle of impact, most probable speeds at the time of impact, possible strengths of the ice, etc. The simulation should produce an estimate of the ice impact load as well as the average ice pressure on the hull. To the best of our knowledge there is one commercially available program at ARCTEC CANADA Limited; another version has been developed by Melville Shipping Ltd. of Montreal for internal use. The most useful data which can be obtained from this program are:
 - · the total impact load
 - · the average ice pressure
 - the extent of contact of ice, i.e. shape and size of the area of contact
 - · where this area is located on the hull.

Several runs may be required to adjust the contact area with the damage location. The availability of more definitive data on the damage circumstances would help in providing a more realistic estimate of the load, pressure, and area of ice contact. It should be noted that the order of magnitude of ice crushing strength should be equivalent to estimates of ice pressure obtained by simple methods. For further information on such simulation methods, reference may be made to papers by Major, et al [B-26] and Noble, et al [B-36].

- (3) Compare extent of ice load with the hull structural details and determine boundaries of a segment of the structure to be modeled. These boundaries should preferably be most rigid, e.g. bulkheads and floors. Establish necessary boundary conditions.
- (4) Prepare a finite element model of the structure (3D model is preferred but a 2D model with lumped stiffeners may be accepted). A simplified ship structure segment as modeled by the finite element method is shown in Figure C.6. Apply external ice loads which have been determined earlier and estimate the "elastic" stresses and strains in various components. Output can be obtained with aid of standard graphics such as principal stress contours in both the shell and frames. Figure C.7 is an example of major principal stress contours in a typical structure. Such stresses can be examined to determine whether or not elastic limits were exceeded. This type of simple, inexpensive elastic finite element solution can produce a fairly good idea about where damage would start. Examination of stress levels would indicate locations on the shell and frames which will likely experience highest stresses. Some approximate correlations with the nature of observed damage can be made at this stage. There are a number of commercially available finite element programs which can be used for this purpose. To list a few:

FIGURE C.6
SIMPLIFIED FINITE-ELEMENT MODEL FOR TYPICAL STRUCTURE

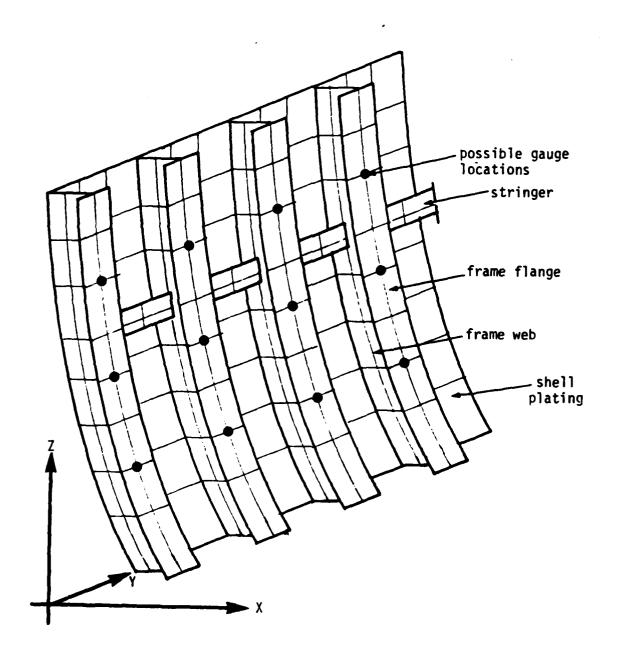
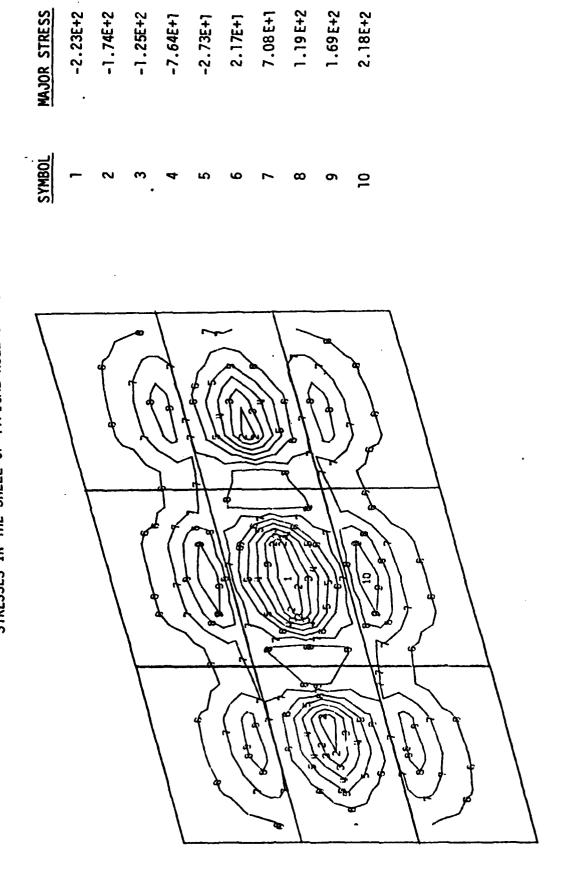


FIGURE C.7 STRESSES IN THE SHELL OF TYPICAL HULL STRUCTURE

には、10mmに対象のでは、10mmでは、10mmである。 マング



- NASTRAN
- ANSYS
- STARDYNE
- STRESS
- MARC

All of these are available world-wide, and further information may be obtained from major suppliers, such as Control Data, Multiple Access, or General Electric.

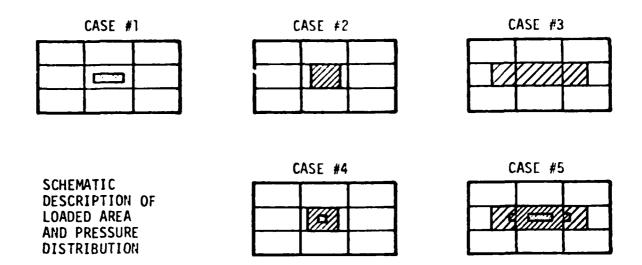
- (5) A more advanced and much more expensive step is to allow the hull material to yield in accordance with a selected bilinear stress-strain relationship. In this case, continuous updating of the stiffness matrix will be maintained to account for the yielding of plate or frame elements of the structure. The cost of this updating is quite high, particularly if a complete solution is desired. For a moderate size model (say 500-1000 elements), consideration of plastic flow can easily increase the cost by ten-fold.
- (6) A study of the influence of ice pressure distribution on the stress distribution and possibilities of failure of the structure can be done by arbitrarily structuring a stepped pressure distribution within the contact area without altering average value or the total ice load. This technique has been used successfully to analyze the structure of the CCGS LOUIS S. ST. LAURENT with some interesting results as to the effect of pressure distribution. These results are illustrated in Figure C.8.

The utilization of elastic solution may be satisfactory to the requirements of damage analysis where the available data on the damage is sketchy. However, more sophisticated evaluation using plastic yield of the material should be appropriate and is justified for situations where more accurate data is available on the damage incident. In fact, a combination of both would be necessary since the economic restraints could only allow one or two runs with plastic yielding in addition to several elastic runs to select the loading conditions for these two.

To date, there has been no complete and documented utilization of the procedure proposed herein. However, several studies have been conducted to investigate stresses and strains in different hull structural components by using FEM. The results appear to be quite informative and useful, suggesting that using the FEM to conduct damage analysis can produce better insight into the nature of stressing of the hull, under variable loading conditions. This can ultimately lead to the understanding of how damage initiates and propagates within the structure and hence, to some informed guidelines for better design of hull structures to withstand extreme ice load with minimal penalty on the weight and cost of the ship.

FIGURE C.8

EFFECT OF CHANGING PRESSURE DISTRIBUTION ON STRESSES IN SHELL AND FRAMES



CASES COMPARED	CONDITION	STRESS	CHANGE
1-2	Equal total loads, increased area, even distribution		plate frame
2-4	Equal total load, same area, changed distribution		plate frame
3-5	Equal total load, same area, changed distribution		plate frame
4-5	Equal central pressure, changed area, increased total	+51% +224%	plate frame

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Mr. A. D. Haff, Chairman, Consultant, Annapolis, MD
Prof. A. H.-S. Ang, Civil Engrg. Dept., University of Illinois, Champaign, IL
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Company, Tulsa, OK

Mr. D. Price, Sr. Systems Analyst, National Oceanic and Atmospheric Administration, Rockville, MD

Mr. D. A. Sarno, Manager-Mechanics, ARMCO Inc., Middletown, OH Prof. H. E. Sheets, Dir. of Engineering, Analysis & Technology, Inc., Stonington, CT

Mr. J. E. Steele, Naval Architect, Quakertown, PA

Mr. R. W. Rumke, Executive Secretary, Ship Research Committee

The SHIP DESIGN, RESPONSE, AND LOAD CRITERIA ADVISORY GROUP prepared the project prospectus and evaluated the proposals for this project.

Mr. J. E. Steele, Chairman, Naval Architect, Quakertown, PA

Mr. J. W. Boylston, Consulting Naval Architect, Giannotti & Associates, Inc., Annapolis, MD

Prof. R. G. Davis, Assistant Professor of Naval Architecture, Dept. of Marine Engrg., Texas A&M University, Galveston, TX

Mr. P. W. Marshall, Civil Engineering Advisor, Shell Oil Company, Bouston, TX

Prof. R. Plunkett, Dept. of Aerospace Engrg. and Mechanics, University of Minnesota, Minneapolis, MN

Mr. C. B. Walburn, Assistant Naval Architect, Bethlehem Steel, Corp.,
Marine Division, Sparrows Point, MD

The SR-1267 ad hoc PROJECT ADVISORY COMMITTEE provided the liaison technical guidance, and reviewed the project reports with the investigator.

Mr. W. J. Lane, Chairman, Consultant, Baltimore, MD

Mr. L. R. Glosten, L. R. Glosten Associates, Inc., Seattle, WA

Mr. P. M. Kimon, EXXON International Co., Florham Park, NJ

Mr. P. W. Marshall, Civil Engrg., Advisor, SHELL Oil Co., Houston, TX

Mr. J. E. Steele, Naval Architect, Quakertown, PA